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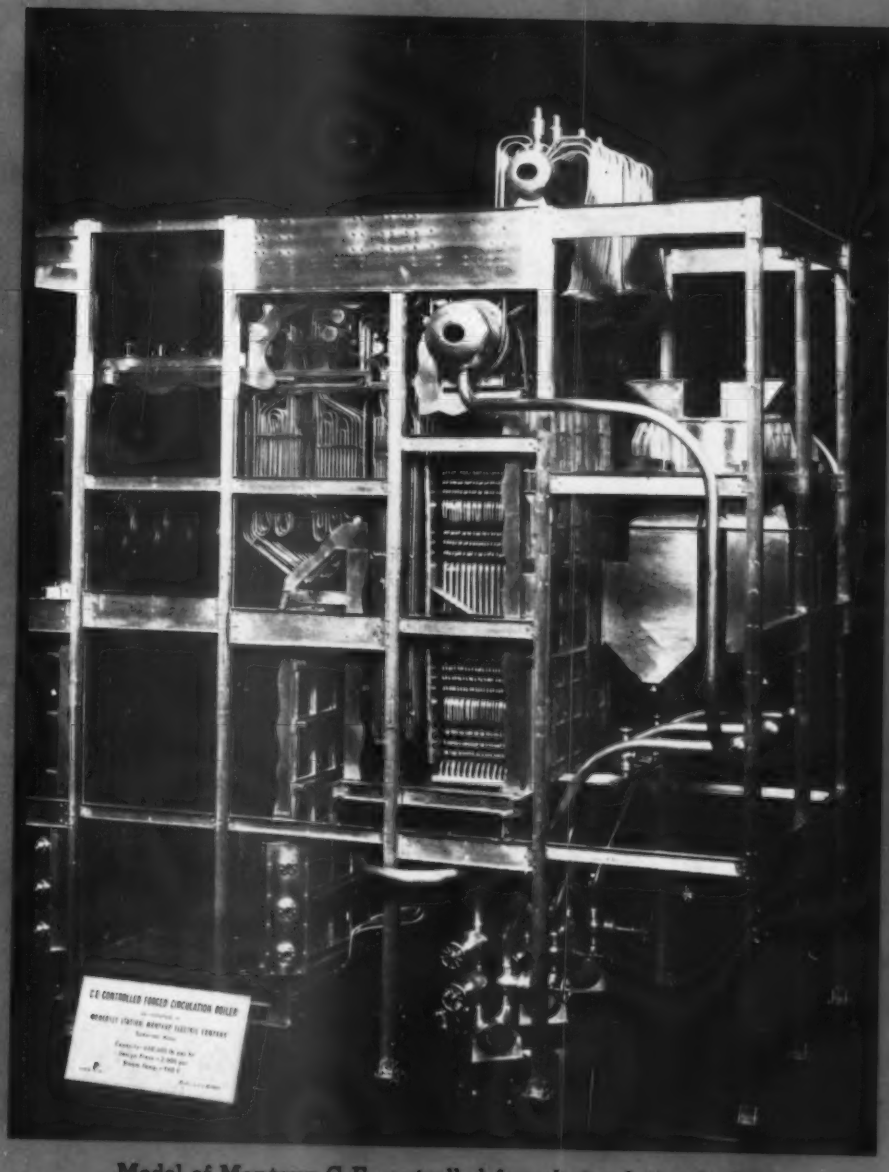


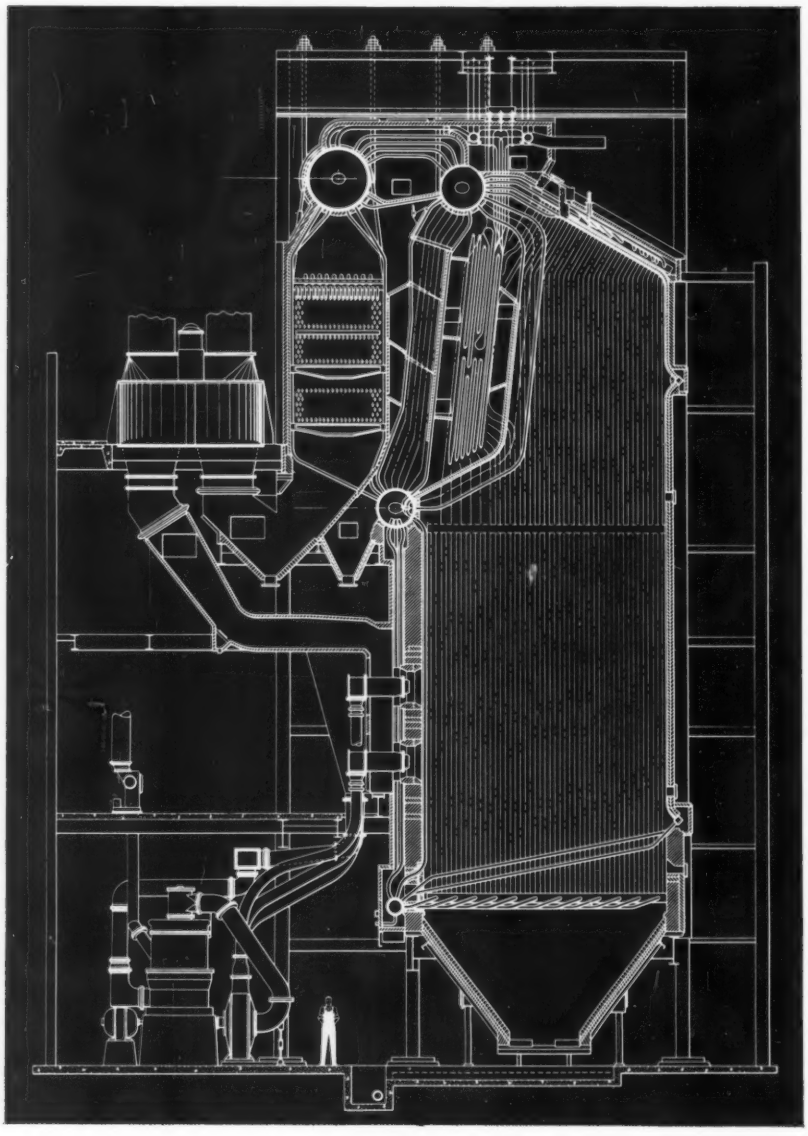
Model of Montaup C-E controlled forced-circulation boiler; for description see page 59

Boiler Plant Serving ATOMIC BOMB Production ▶

Grate Heat Release vs Combustion Rate in Stoker Calculations ▶

MANCHESTER ST. STATION *Repeats*

WITH ANOTHER BIG C-E UNIT



A C-E Steam Generating Unit, designed for a pressure of 1350 psi, a total steam temperature of 915 F and a maximum continuous capacity of 430,000 lb of steam per hr, was placed in service in 1941 by the Narragansett Electric Company of Providence, R. I., in their Manchester Street Station. A new unit has recently been ordered.

A-920

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C-E PRODUCTS INCLUDE ALL TYPES OF BOILERS, FURNACES, PULVERIZED FUEL SYSTEMS AND STOKERS; ALSO SUPERHEATERS, ECONOMIZERS AND AIR HEATERS

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME 17 **NUMBER 4**

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OCTOBER 1945

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Editorial

Research to the Fore

Many of the larger companies have announced plans for extensive research, some involving the construction of large-scale laboratories. Also, several engineering society meetings are scheduled to discuss this important subject.

This is not surprising inasmuch as new commercial products were almost completely sidetracked during the war period and the buying public is in an expectant mood concerning improved products of all kinds. The engineering field is no exception and has already established many individual and cooperative projects. In such development, wartime experience will be drawn upon and adopted, where possible, to peacetime advancement. Moreover, competitive markets of the near future will necessitate products based on research.

It will be recalled that President Truman, in his message to Congress, urged the adoption of legislation for the establishment of a single Federal research agency, not only to coordinate the present diversified research now being conducted individually by various governmental agencies, but also to extend and promote research in the basic sciences, public health and medicine. He also proposed that financial assistance be provided in the form of scholarships to young men and women of proved scientific ability. The fruits of such research would be made freely available to industry, agriculture and academic institutions. The President added, however, that such federal research should not impair the freedom of private scientific research.

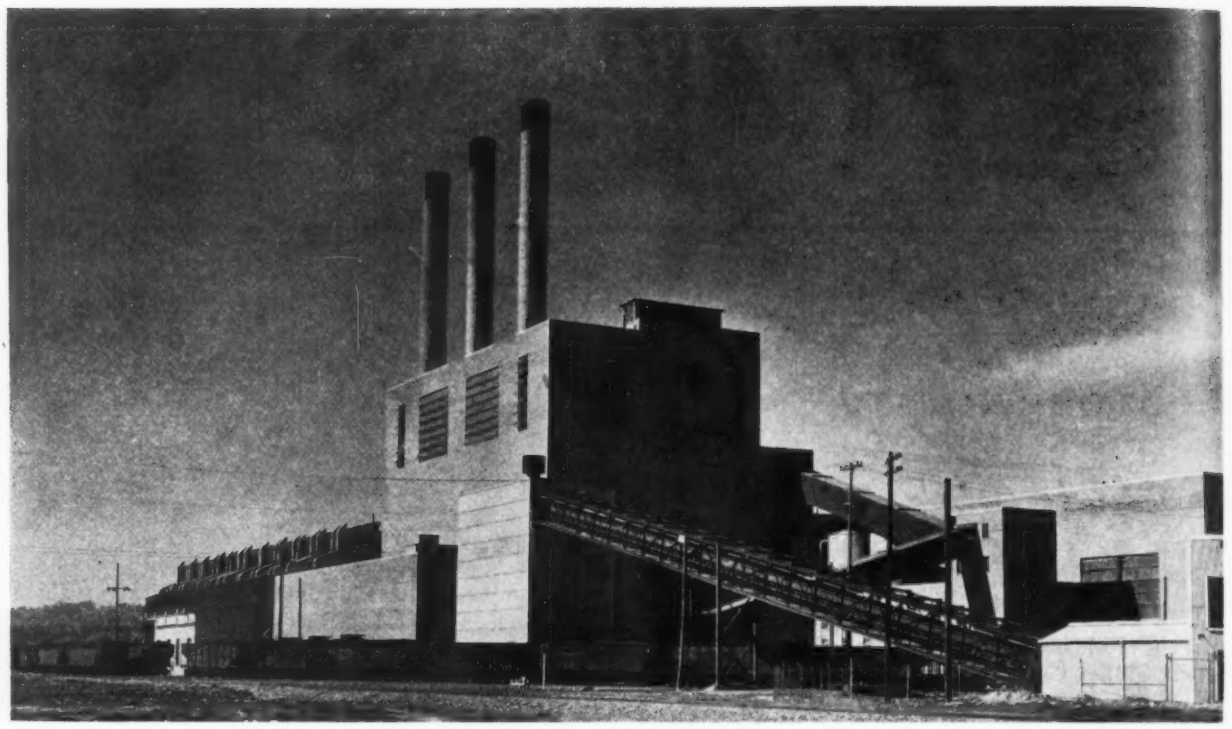
If this last-mentioned assurance is followed in any legislation that may come out of the proposal, the efforts of the Government and of private industry can be made to serve a complimentary purpose. Any other course would stifle development.

Automatic Control for Spreader Stokers

During the last few years spreader-stoker firing has become very popular for both small and medium size boiler plants; and because of its adaptability to coals having a wide range in characteristics it is likely to find still wider application in the years ahead.

However, the full advantage of this type of firing, particularly with fluctuating loads, can be realized only under proper automatic control, as it is difficult under average conditions to maintain the correct fuel and air ratio with manual control.

This fact should be well understood by those contemplating the installation of spreader stokers; otherwise unsatisfactory operation may result and unjustly reflect upon the stoker.



Main Power Plant at Oak Ridge

Boiler Plant Serving ATOMIC BOMB Production

Description of the main boiler plant at Oak Ridge containing three mammoth high-pressure steam-generating units which furnish steam to the turbines. These units are tangentially fired with pulverized coal and have slagging-bottom furnaces. Electrostatic fly-ash collectors and complete automatic combustion control are provided.

By H. M. LOWENSTEIN*

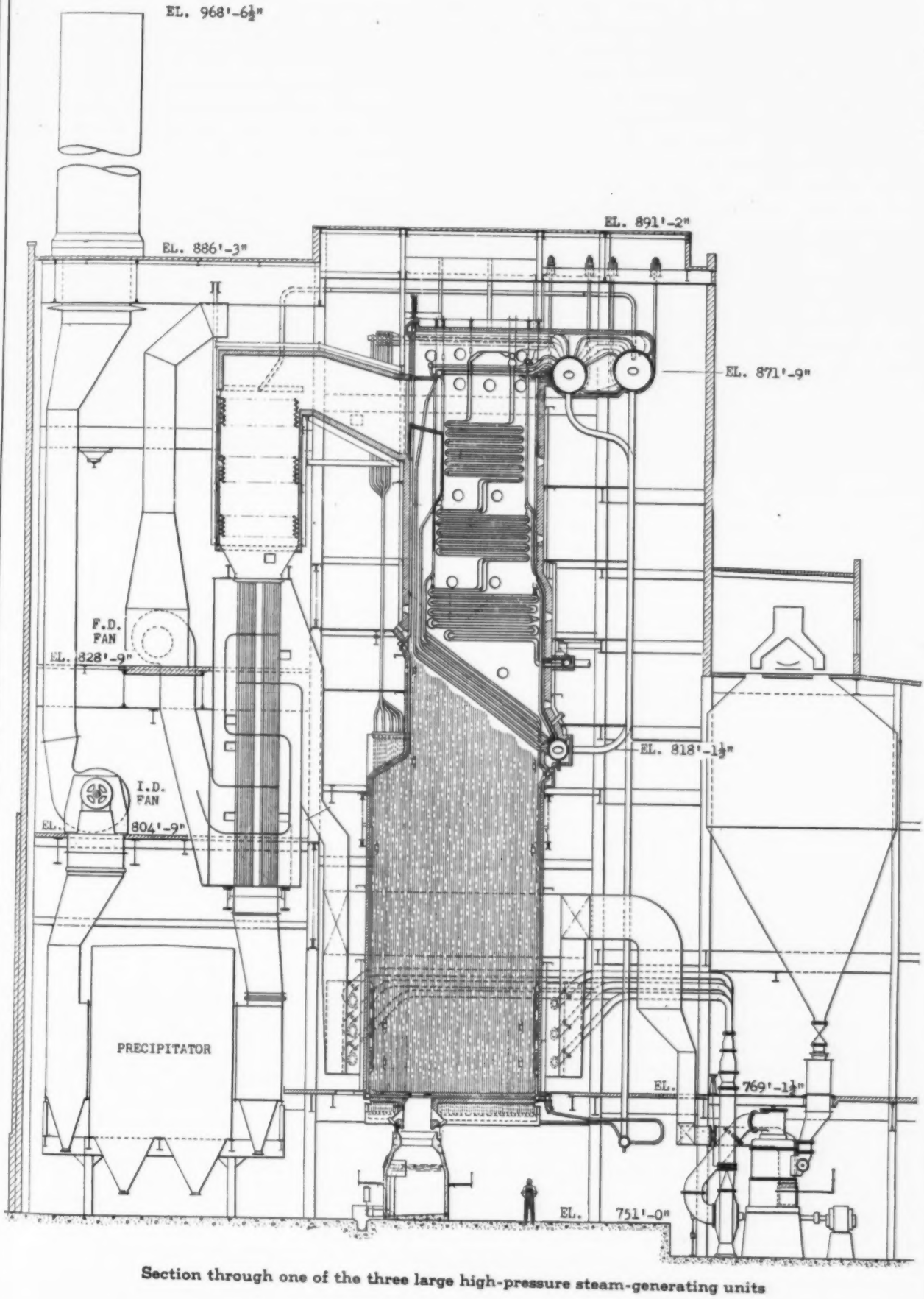
EVER since that memorable day early in August when the first atomic bomb practically obliterated Hiroshima, this new weapon of destruction has been the subject of widespread discussion and disposition of its attendant secrets has deeply concerned official thinking. But, regardless of the ultimate decision as to this latter aspect, it is well known that the project represented a vast expenditure of money for plant and equipment and that huge amounts of both steam and power were required. How this steam was produced, however, is aside from any secrets involved in the production of the atomic bomb, especially as the principal steam plant at Oak Ridge followed accepted practice and as much of its major equipment was intended for installation in a large utility power station. Nevertheless, from the standpoint of power engineers, it is a most interesting installation, not only because of the size, but also because it embodies many of the latest design features. For this reason, the following description will deal entirely with the boiler plant at Oak Ridge, Tenn.

Description of Steam-Generating Units

The main boiler plant, for supplying power by a number of turbine-generators, contains three large high-pressure steam-generating units furnished by Combustion Engineering Company. These are fired with pulverized coal, and each has a rated capacity of 750,000 lb of steam per hour at 1325 psi and 935 F, but capable of producing a maximum of 825,000 lb per hr. They are of the three-drum bent-tube type, equipped with both economizer and tubular-type air preheater, a completely water-cooled furnace of the slagging-bottom type and tangentially fired. Some idea of the size of these units may be gained from the fact that the distance from the basement floor to the centerline of the upper drums measures approximately 120 ft and the furnace measures 56 feet from the floor to the first boiler tubes.

Referring to the accompanying cross-section, the steam take-off drum is 60 in. diameter, the steam-separating

* Mr. Lowenstein was granted leave of absence from the Engineering Department of Combustion Engineering Company in April 1943 to join the staff of Kellex Corporation where he was intimately associated with the design and installation of the steam facilities at Oak Ridge. He has now resumed his former connection.



Section through one of the three large high-pressure steam-generating units

drum 54 in. and the lower drum 30 in. The main boiler-tube bank consists of four staggered rows of 3-in. tubes which slant upward from the lower drum, across the furnace, and combine to form vertical rows in the same plane and terminate in a round header. The latter is connected to the steam-separating drum by $3^1/_2$-in. fin tubes which form the roof of the furnace. Two rows of $3^1/_2$-in. uptake tubes connect the lower drum with the steam-separating drum through a header. The outside tubes are finned and form the front wall of the boiler proper. These drums are also connected by two 10-in. downcomers. The steam take-off drum is located in front of and slightly above the steam-separating drum and is connected with the lower drum by a 10-in. downcomer.

The furnace, with a volume of 47,600 cu ft, is completely water-cooled with 3-in. closely spaced bare bifurcated tubes on the front, rear and side walls. Its bottom is water-cooled with 3-in. tubes having cast-iron block covering. The water walls are fed from the upper boiler drums by six 10-in. downcomers through a distributing header. They are suspended from the steel girt just below the level of the lower drum so that the furnace is free to expand downward or upward uniformly from the point of suspension. Slag discharges continuously at the bottom, through a slag ring, to a slag tank from which it is removed by the ash-sluicing system to an ash sump in the building; thence to an outside pit.

The superheater is of the Elesco continuous-loop type and is divided into three sections, the top and intermediate sections being somewhat shorter than the bottom section. This arrangement permits a bypass from the upper sections for the regulation of superheat. A vertical sliding damper is located at the boiler outlet and is arranged so that, as it opens the bypass connection, it also closes off the normal gas outlet permitting a wide range of control. This damper is divided into three sections with an operating cylinder for each, the cylinders being actuated by a master control on the boiler panel.

Elements of the superheater are hung at the front from the inside row of uptake tubes from the lower drum, and at the rear from the front water-wall-riser tubes. The tubes of the superheater are spaced so that alternate elements line up with the boiler tubes at the front and rear, and the other elements are located centrally in the spaces between the boiler tubes. This affords clear lanes for lancing during operation through doors provided in the walls for that purpose, and is particularly advantageous with a high-ash coal of low ash-fusing temperature.

The economizer, of the continuous-loop type, is located at the rear of the unit and arranged in two sections with separate inlet and outlet headers at each side of the unit. Water enters at the bottom and passes upward counter to the gas flow. Also, at the rear of the unit and below the economizer is the air preheater which is of the tubular type with gas flow straight through from top to bottom. Air enters at the bottom and makes three passes across the tubes, leaving at the top, so that air and gas are counterflow.

In the steam-separating drum, which first receives all the steam generated in the boiler tubes and water walls together with the accompanying circulating water, there is a system of baffles and reversing hoods that hydraulically separates the bulk of the circulating water from the generated steam which then passes through the circulating tubes to the 60-in. take-off drum. Here it passes through a steam washer in which most of the entrained solids are removed by relatively pure feedwater. The steam then passes upward at low velocity which allows any excess spray carried from the washer to drop out; and finally through a screen drier to remove any remaining moisture.

It will be noted from the cross-section that in the design of these steam-generating units, particular attention was given to means for preventing the boiler bank, superheater and water-wall surfaces from being fouled by slag and dust. For the removal of such accumulations as form, a complete system of mechanical soot-blower units has been provided, in addition to an ample number of access ports for hand lancing. The soot blowers for the boiler, superheater, economizer and water walls are of the retractable type and those for the air preheater are of the straight-line type with chain-operated rack and pinion traversing nozzle elements.

Forced- and Induced-Draft Fans

Each steam-generating unit incorporates two forced-draft fans, with adjustable-vane control, of 96,000 cfm capacity at rated output of the boiler. These are driven by dual-speed motors of 225–400 hp, depending upon the speed. The induced-draft fans, two per unit, are equipped with adjustable-vane control. They are of 167,000 cfm rating and driven by dual-speed motors.

Pulverizers and Burners

Three C-E Raymond bowl mills serve each unit. These are supplied with coal through automatic scales and are rated at 13.1 tons per hour each with 80 per cent pulverization through a 200-mesh and coal up to 15 per cent moisture and 45 to 55 grindability. Each mill is driven by a 350-hp, 900-rpm motor.

Pulverized coal from the mills is distributed to twelve tangential burners arranged three in each corner of the furnace. The burners are adjustable manually for tilting vertically in order to accommodate the burning and fusing characteristics of various coals and to assist superheat control. Oil ignition torches in each corner are of sufficient capacity to put the boiler on the line.

To assure the proper sequence in starting and to prevent dangerous or undesirable furnace conditions in case a motor fails to function, an electrically interlocked system has been provided for the motors driving the fans, mills and coal feeders.

Coal Handling

Briefly, the coal-handling equipment functions as follows:

Coal is received by rail over two track hoppers with a duplex hopper for each track; and each duplex hopper delivers to a duplex shaking feeder. A system of conveyors is used to transport and elevate the coal to the boiler house, and a coal crusher is employed to reduce the lumps of coal to a size that will pass through a $1^1/_2$-in. screen and also reject foreign material. A motor-driven traveling tripper discharges the coal to the bunkers. A coal sampler, magnetic pulley and weightometer are part of the equipment.

Boiler Feed Pumps

Six 8-in. six-stage boiler feed pumps serve the three steam-generating units. These are each of 600,000 lb per hr capacity against a discharge head of 1600 psi. Four

are motor-driven and two turbine-driven, by 1750-hp 2300-volt motors and 1540-hp turbines. The turbines take steam at boiler pressure and exhaust at 140 psi.

These high-pressure feed pumps have single-suction impellers and are hydraulically balanced by a combination balancing disk and drum which compensates for the pump thrust at all capacities by controlling the leakage between the balancing disk faces in a radial plane and through a constant annular gap. Since the pump losses are converted into heat taken up by the feedwater, excessive temperature rise at low rates of flow is avoided by means of a bypass in the discharge. This bypassed water is discharged to the water-storage tanks or to the hot boiler feed header and the flow is automatically regulated for a minimum flow through the pump.

After passing through the feedwater heaters the feedwater enters the economizer at 350 F.

Makeup water is taken from the river and before being evaporated is passed through a 75,000-lb per hr deaerating heater. It then is handled by three evaporators of 25,000 lb per hr capacity each. A minimum amount of chemical treatment is required for which chemical feed pumps are installed, feeding ahead of the deaerator or directly to the boiler as required.

Combustion Control

Complete automatic combustion control and water-level control is employed. The former is arranged for operation under any one of the following three conditions.

1. Full automatic, wherein the necessary adjustments are made automatically from variations in steam pressure.
2. Semi-automatic (boiler manual), wherein the rating of each boiler is changed by the operation of a single rating device for that particular boiler.
3. Hand control, by which the adjustments of the various component units are controlled independently from the boiler control board.

The control is so designed that any of the boilers can be operated by one of the foregoing methods, while one or both of the other boilers are controlled by one of the other methods. Also, one or two boilers can be operated at constant rating, with the swings being taken by the others, or other, in whatever ratio desired. All of these control functions can be retained with one, two or three pulverizers in operation on any boiler and, at the same time, the operator can then cut in or out without affecting boiler performance.

Fly Ash Collection

The coal burned contains about 15 per cent ash and approximately half is discharged through the slagging bottom of the furnace; the remaining half passes up through the boiler as fly ash. It is estimated that about 85 per cent of this fly ash is fine enough to pass through a 325-mesh screen. To collect this fly ash an electrical precipitator was installed between the air preheater outlet and the induced-draft fan inlets of each boiler.

The V-collector elements of the precipitator are cleaned by a vibrating (rapping) device and the fly ash falls to hoppers below the precipitator sections from whence it is removed periodically by an automatically operated hydraulic-vacuum system.

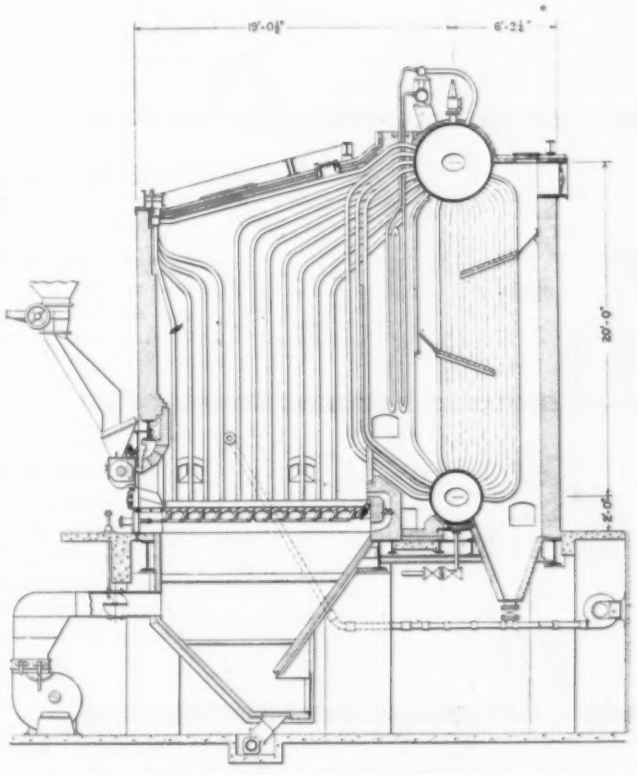
There are three 12-ft diameter steel stacks, one for each steam-generating unit, that extend 102 ft above the roof which, in turn, is 135 ft above the basement floor.

A test run on one of the boilers at 724,000 lb per hr output and 1295 psi at the superheater outlet, 932 F steam temperature and water entering the economizer at 315 F, when burning 11,505 Btu coal, showed an overall efficiency for the unit of 89.9 per cent.

It may be of interest to mention that the first of the three boilers was under steam 10 months after receipt of the order and only $4^1/_2$ months elapsed from the time the first drum was hung until the first unit was ready for steaming.

Heating Plant

As previously mentioned, the steam plant described furnishes power through a number of turbine-generators. Located in another area there is a boiler plant which supplies steam at lower pressure for both heating and process use. This plant contains six C-E two-drum bent-tube boilers, three of 50,000 lb per hr rated capacity and three of 40,000 lb per hr. They are fired by spreader stokers and produce steam at 175 psi, 477 F total temperature. Each unit is served by a forced-draft fan. There are six boiler feed pumps, four steam-driven and two motor-driven. Two complete hot-process lime and soda water-softening systems for makeup requirements of 135,000 lb per hr, total, are provided. Automatic combustion and water-level controls are also installed.



Section through one of the heating plant units

Draft is furnished by two 9-ft diameter radial-brick stacks 175 ft high.

The power boiler and steam plants described were engineered by the Kellex Corporation, representing the War Department and U. S. Army Corps of Engineers, Manhattan District, with Sargent & Lundy acting as consulting engineers and J. A. Jones Construction Company doing all construction work.

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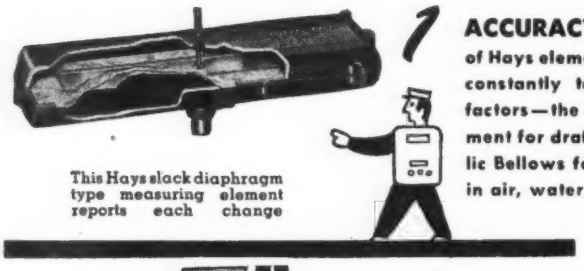
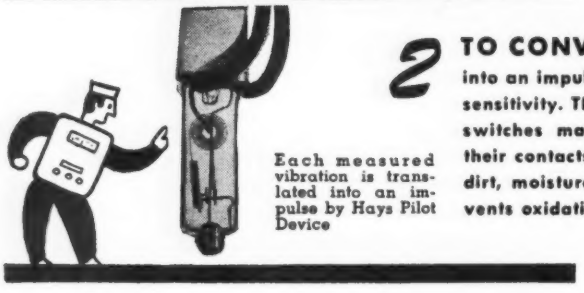


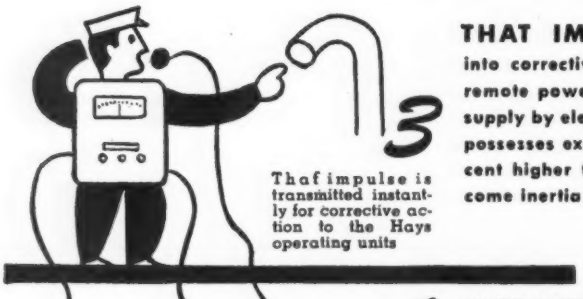
This Hays slack diaphragm type measuring element reports each change

1 ACCURACY A CONSPICUOUS FEATURE of Hays elements for measuring the minute changes constantly taking place in variable combustion factors—the Hays diaphragm type measuring element for draft and low pressures; and Hays Metallic Bellows for measuring steam or high pressures in air, water or oil.



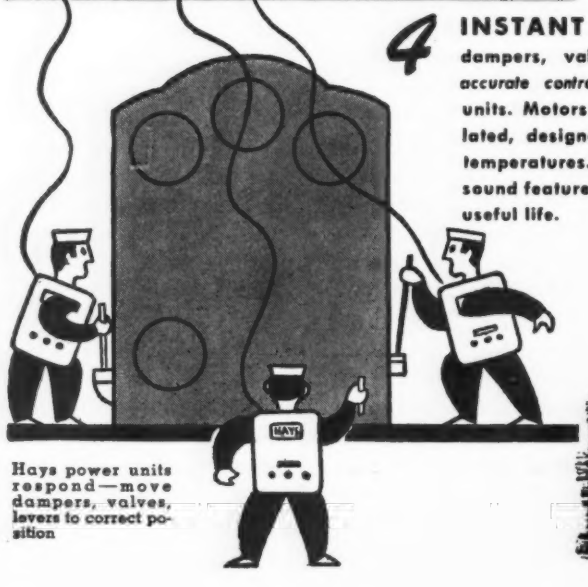
Each measured vibration is translated into an impulse by Hays Pilot Device

2 TO CONVERT EACH MEASUREMENT into an impulse calls for a pilot device of extreme sensitivity. The Hays pilot consists of two mercury switches magnetically operated. Fully enclosed, their contacts are effectively protected from dust, dirt, moisture; and blanketing with nitrogen prevents oxidation—a guarantee of long life.



That impulse is transmitted instantly for corrective action to the Hays operating units

3 THAT IMPULSE IS TRANSLATED into corrective action, delivered instantly to the remote power units operating fuel feeder and air supply by electrical transmission. The Hays system possesses excessive starting torque—25 to 75 per cent higher than moving power—ample to overcome inertia and create quick action.



Hays power units respond—move dampers, valves, levers to correct position

4 INSTANT ACTION FOR MOVING dampers, valves or levers *to the right point for accurate control* is the function of Hays power units. Motors are fully enclosed, effectively insulated, designed for installation in high ambient temperatures. Manual operation is available. Many sound features assure easy maintenance and long, useful life.

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COMBUSTION INSTRUMENTS AND CONTROL

MICHIGAN CITY, INDIANA, U.S.A.

Grate Heat Release vs Combustion Rate in Stoker Calculations

The shortcomings of expressing fuel-burning rates in terms of coal burned per square foot of grate surface are contrasted with the advantages of employing the heat release per square foot per hour. The former is indefinite as a means of comparison because of the varying heat contents of coal, whereas the latter is not only a direct measure but also ties in with the widely accepted practice of expressing boiler output in million Btu per hour. Several charts are included for use with the grate heat-release method.

By H. G. MEISSNER

Combustion Engineering Company

THE concept of measuring the rate of fuel consumption on a grate by the grate heat release (Btu per sq ft per hr) instead of by the combustion rate (pounds of fuel per sq ft per hr) is not new, but the latter method has been employed for so long that it has acquired an accepted status. However the advantages of the grate heat-release method become so obvious when the fundamentals of combustion are fully understood, that it is believed this method, which uses the product of the heating value of the fuel by the combustion rate as the basic factor, will eventually supersede its present counterpart to the benefit of all concerned.

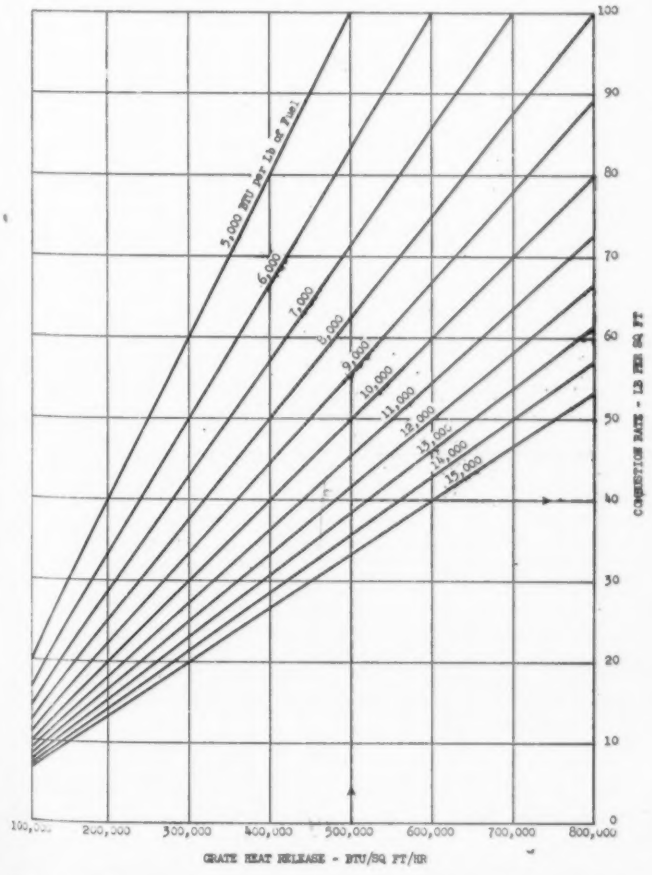

Fig. 1—Relation between grate heat release in Btu and combustion rate in pounds per square foot

Experience has shown that many solid fuels, including most kinds of coal in common use, can be burned satisfactorily at grate heat-release rates of 450,000 to 500,000 Btu per sq ft per hr. The following tabulation shows that for the latter value the corresponding fuel weights range from 75 lb per sq ft per hr in the case of lignite, to 34 lb for low-volatile West Virginia coal; and if such fuels as wood, bagasse, etc., are included, the weight of fuel per square foot considerably exceeds 100 lb. These values are all well within commercial practice, and their wide range demonstrates one of the difficulties experienced when the combustion rate basis is employed.

COMBUSTION RATE IN POUNDS PER SQUARE FOOT PER HOUR FOR TYPICAL FUELS WHEN FIRED AT GRATE HEAT RELEASE OF 500,000 BTU

Fuel	Btu per Pound as Fired	Combustion Rate, Pounds per Sq Ft
N. Dakota lignite	6,700	74.6
Colorado lignite	9,941	50.4
Illinois bituminous	10,989	45.6
Ohio bituminous	12,733	39.3
Penna. bituminous	13,700	36.5
Penna. semi-bituminous	14,096	35.5
W. Va. semi-bituminous	14,688	34.1
Penna. anthracite	12,472	40.1
Wood, bagasse, etc.	4,500	111.0

Another serious objection to the pounds per square foot basis is that there is a marked difference in the heating values of the fuel, and weight of fuel required, depending on whether it is taken on a dry or as-fired basis. In the case of lignite, for example, the heating value on a dry basis may be 10,500 Btu per lb, which corresponds to 6700 Btu per lb on an as-fired basis. When fired at a grate heat release of 500,000 Btu, the combustion rate on a dry basis would be 47.6 lb, whereas on the as-fired basis the combustion rate corresponds to 74.5 lb per sq ft. As the moisture in certain coals varies widely, depending on weather and handling conditions, the chances of confusion are evident when the weight basis is employed.

The chart, Fig. 1, gives in convenient form the relationship between combustion rate in pounds, and grate heat release in Btu per sq ft, for the normal range of coal heating values, so that one not familiar with the latter basis can quickly compare it with these values.

The grate heat release basis fits in well with the modern method of figuring boiler performance, that is, the "Million Btu" system. In this method the total Btu in the steam, as determined from steam tables or a chart similar to that shown in Fig. 2, is divided by the assumed efficiency, to arrive at the required heat input to the furnace. These values come out in terms of million Btu, which accounts for the name of the system.

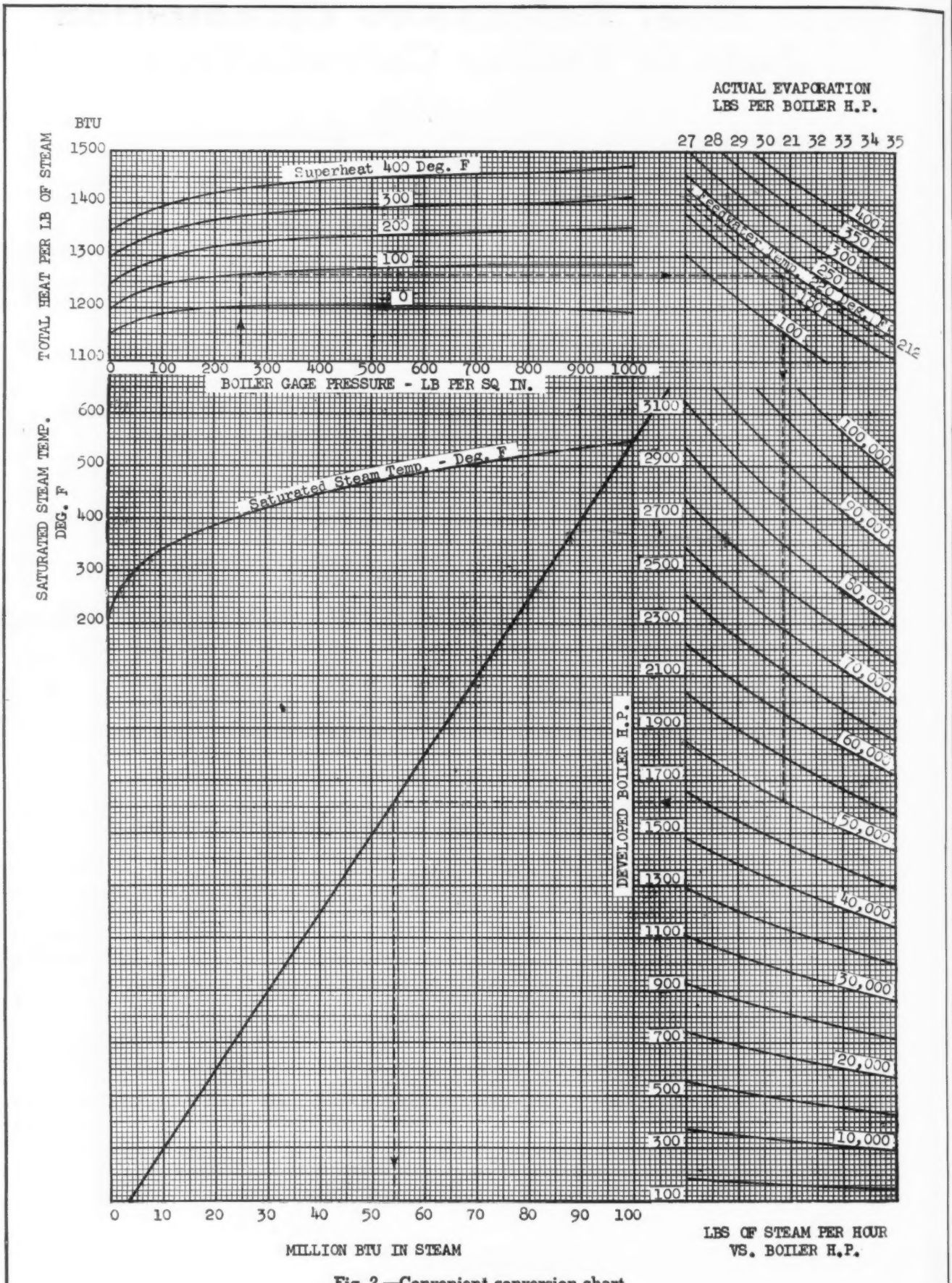

Fig. 2.—Convenient conversion chart

For example, a boiler designed to generate 50,000 lb of steam per hour at 250 psi pressure, with 100 deg F superheat, and supplied with feedwater at 212 F would require a total heat input in the steam of 54 million Btu per hr. At an assumed boiler efficiency of 75 per cent the heat input to the furnace would then have to be 72 million Btu per hr.

Assuming that the fuel to be used can be burned satisfactorily at 500,000 Btu per sq ft per hr grate heat release the required grate area is 144 sq ft. Knowing the furnace width, the stoker dimensions are then established. In practice, tabulations showing the allowable combustion rates in Btu per sq ft are prepared, based on past experience, test data, etc., the various fuels being divided into several classifications, which take account of their combustion characteristics. Furnace design and water-wall construction are important considerations in the preparation of such tabulations.

One such classification includes five fuels, ranging from eastern low-volatile through Pittsburgh, and midwestern bituminous, sub-bituminous and lignite. While this classification suits the particular stoker involved, separate classifications might be necessary for other types. For example, for the spreader stoker the coking or free-burning characteristics of the fuel, or the fusion temperature of the ash, have relatively little effect on performance, yet these characteristics are critical items in the case of underfeed stokers.

FUEL	ULTIMATE ANALYSIS					Moisture	BTU VALUE			AIR REQUIRED		
	C	H	O	S	A		As Fired	Dry	Moisture and Ash Free	Lbs/Lb of Fuel	Lbs/Lb of Combustible	Lbs per 10,000 BTU
N. D. LIGNITE	39.4	6.8	43.8	0.7	9.3	36.2	6,700	10,500	12,300	5.0	9.2	7.54
COL. "	57.8	6.0	31.0	0.4	4.8	20.7	9,941	12,500	13,300	7.5	9.9	7.53
ILL. BITUMINOUS	60.9	5.8	19.2	3.7	10.4	12.7	10,989	12,600	14,300	8.4	10.8	7.66
OHIO "	70.5	5.4	11.2	2.9	10.0	5.2	12,733	13,450	15,000	9.7	11.2	7.63
PA. "	75.7	5.4	10.3	1.2	7.4	3.5	13,700	14,200	15,550	10.3	11.3	7.50
PA. SEMI-BIT.	80.7	4.3	3.2	1.4	10.4	1.2	14,096	14,250	15,950	10.8	12.0	7.65
W. VA "	84.3	4.7	5.2	0.7	5.1	3.1	14,688	15,150	16,000	11.2	12.1	7.65
PA. ANTHRACITE	75.2	2.8	4.1	0.8	17.1	2.1	12,472	12,750	15,450	9.6	11.9	7.66
										THEORETICAL AIR PER 10,000 BTU - AV.		7.60

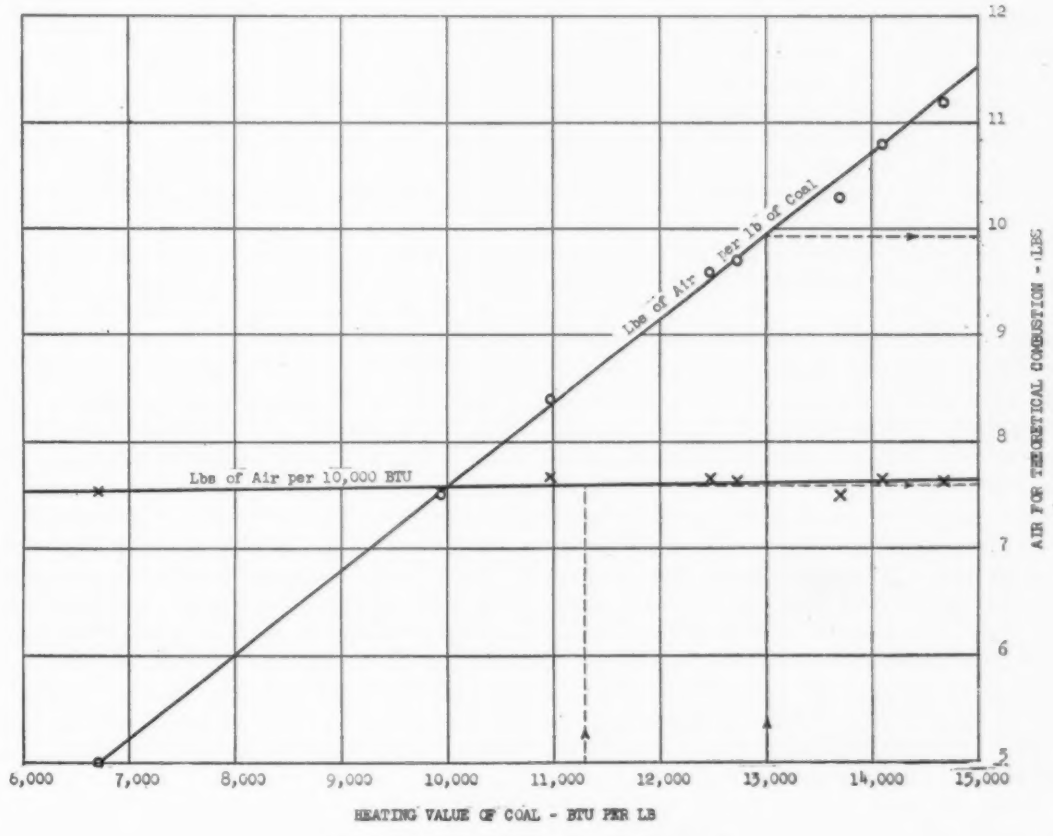

Fig. 3—Theoretical air requirements

Similar tabulations are prepared, showing allowable furnace heat releases, these values being dependent partly on the type of fuel, and largely on the furnace construction, especially the amount and distribution of the water-cooled surfaces. For example, it might be satisfactory to burn a midwestern bituminous coal in a water-cooled furnace at the rate of 35,000 Btu per cu ft per hr; while in a refractory-lined furnace this rate should be reduced to about 30,000 Btu to avoid side-wall slagging.

The required furnace size is, therefore, determined in the above example by dividing the allowable heat release of 35,000 Btu into the furnace heat input of 72 million Btu which works out at a little over 2000 cu ft for a water-wall furnace.

It is evident from the foregoing that it is possible to follow through the selection of the stoker without actual use of the pounds of coal burned, but if this value must be determined to meet specification requirements or to calculate the size of the coal hopper or conveyor capacity, it is readily found by dividing the unit heating value of the fuel into the furnace heat input. This gives the coal weight in pounds per hour. When this value is divided by the grate surface as determined above, the combustion rate in pounds per square foot per hour is the result.

It will be noted that the Million Btu method makes no reference to the more or less obsolete terms boiler horsepower, per cent of rating or factor of evaporation, all of which terms were formerly considered as essential to combustion calculations. They may still be determined when required, as the total Btu in the steam divided by 33,500 gives the developed boiler horsepower which is then divided by the horsepower rating of the boiler (square feet of heating surface divided by 10) to get the per cent of rating. The factor of evaporation has become obsolete, as all desired information can be secured without its use, but the net heat input per pound of steam has already been determined so it is readily calculated.

An important contributing factor in the gradual elimination of the terms boiler horsepower and per cent of rating has been the increasing use of water walls, which are frequently a large part of the total heat-absorbing surface, as well as increasing use of heat-recovery equipment such as economizers and air heaters, and superheaters far larger than those formerly used, necessitated by the high steam temperatures which are now common practice. While such equipment absorbs a large proportion of the heat liberated in the furnace, it cannot be considered as boiler heating surface as this term was defined in the past.

The theoretical air requirements of a wide variety of fuels, ranging all the way from lignite to anthracite, are practically identical per 10,000 Btu in the fuel, as shown in the tabulation and chart, Fig. 3, which averages out at 7.6 lb. There is, therefore, a direct relationship between the boiler output, the furnace heat input and the amount of combustion air required, so that the Btu generated, per square foot of grate surface becomes a function of the boiler output and a measure of the velocity of air flow through the fuel bed, as well as the rate of gas flow through the furnace and boiler.

From the above relationship it follows that for any given boiler output and efficiency, the combustion air requirements remain constant, even though the heating value of the fuel may vary. This fact makes it possible to design a boiler and furnace, and select fan equipment, capable of burning a wide variety of fuels, yet being in line as to capacity for any of them.

The selection of both forced- and induced-draft fans is, therefore, greatly simplified by use of this relationship, and the chart, Fig. 4, shows how this is accomplished for a particular type of stoker. The excess air and static pressure requirements of the various stokers will, of course, necessitate individual curves for each type, these curves being based on practical operating experience.

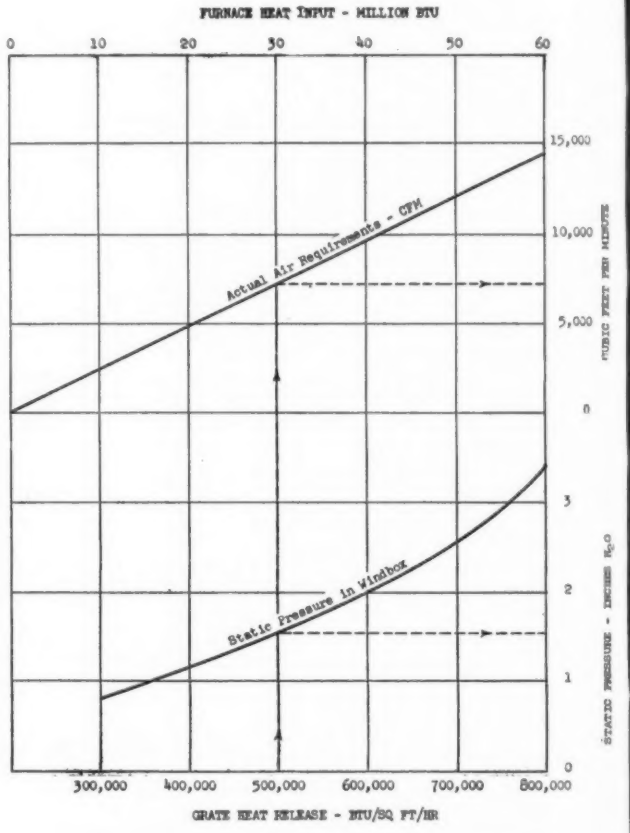

Fig. 4—Curves for forced-draft fan selection

When changing fuels in a plant, very little readjustment in the air supply may be required, although the coal feed rate may have to be changed materially. For example, the change from a high volatile Pittsburgh coal having 13,700 Btu per lb to an Ohio coal of 12,733 Btu per lb might be made with no change in efficiency so that the total air requirements would remain the same; yet the rate of coal feed would have to be changed by almost ten per cent at the same boiler output.

This direct relationship between the boiler output, Btu in the coal burned and the air requirements, has been put to good use by the combustion-control manufacturers, who have so designed their equipment that for each increment of load, the controller will supply the correct quantity of air. In order to compensate for the variable heating values of different fuels, the rate of fuel feed is adjusted manually, by means of a fuel-air ratio dial or similar means, this adjustment being checked by means of an Orsat, CO_2 recorder, or steam flow-air flow

meter. This latter instrument shows by means of two pens, one of which measures the steam output and the other the rate of air flow through the furnace, the ratio between these two factors at all ratings. It is understood, of course, that the excess air requirements of a furnace vary materially with the boiler output, from as much as 100 per cent (9 per cent CO_2) at low ratings

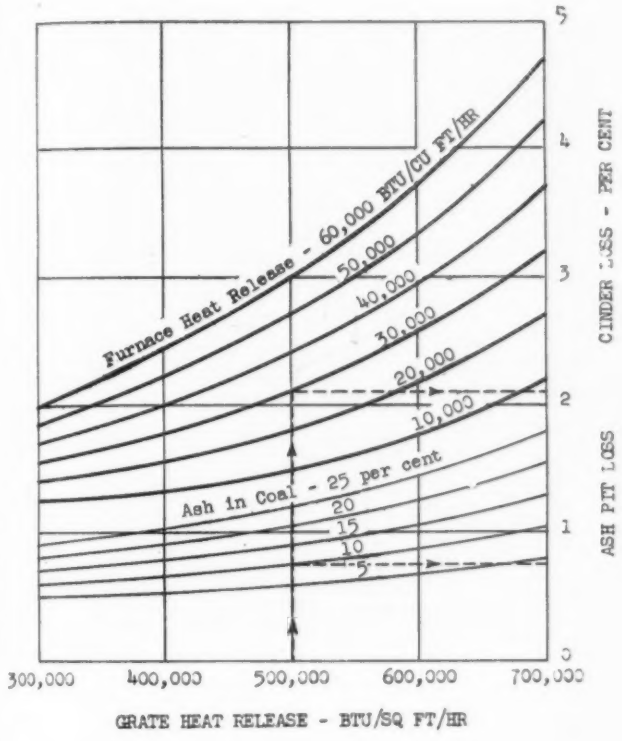

Fig. 5—Carbon loss determination

to possibly 30 per cent or less (14–15 per cent CO_2) at full load.

The steam flow-air flow meter is adjusted to compensate for this variation, but in using a CO_2 recorder or Orsat, the ratio between boiler output and CO_2 must be constantly kept in mind. In a given furnace it may be practical to operate at 14 per cent CO_2 at full load, while at light load the CO_2 should be reduced to 9 or 10 per cent.

It has been said that it is the supply of air rather than the supply of coal that controls the boiler output, and this is literally true, as the above relationships show.

Even in the case of such widely divergent fuels as lignite and Pocahontas semi-bituminous coal, having, respectively, 7000 and 14,000 Btu per lb, so that the rate of fuel feed would vary by approximately 2 to 1, the air requirement per unit of steam output varies by less than ten per cent, equivalent to the ratio of the relative efficiencies.

Other relationships become clear when the fuel consumption is considered on the Btu basis, rather than on the pounds per square foot rate. For example, the cinder carryover from the furnace is largely controlled by the velocity of air flow through the grates, and the corresponding velocity of gas flow through the furnace. For a given size coal the amount of cinder carried out of the furnace should, therefore, vary as a function of the grate heat release. The curves in Fig. 5 indicate that this is in accordance with test data.

It is possible to burn a 7000-Btu lignite at a 70 lb per sq ft per hr combustion rate, corresponding to a 490,000 Btu per sq ft per hr heat output, on the same grate and with practically the same rate of air flow, as will fire a 14,000-Btu bituminous coal at a 35-lb rate, which again corresponds to 490,000 Btu per sq ft per hr. Yet a 70-lb rate on the 14,000-Btu coal would be considered excessive in stationary practice as the increased rate of air flow at this Btu heat output would more than double the cinder carryover and carbon loss.

It should be noted that in locomotive practice, where much higher combustion rates are carried, maximum capacity rather than optimum efficiency is desired.

The CO_2 vs rating relationship is logically based on the grate heat release method, as the excess air required for satisfactory operation with any fuel is largely dependent on the furnace temperature, which, in turn, is a function of the grate heat release. Experience has shown that for certain stokers the optimum furnace conditions as regards CO_2 are reached at between 400,000 and 500,000 Btu grate heat release, and the accompanying typical curve, Fig. 6, has been drawn on this basis. Each type of stoker requires individual study and its own set of curves for the fuel classifications as noted above.

Prior to the now general use of steam-flow meters, the average operator had little knowledge of his steam requirements and in selecting a boiler size he had to depend largely on his experience or that of his associates. Nowadays the steam demands are generally known so that boilers can be selected on a steam output basis.

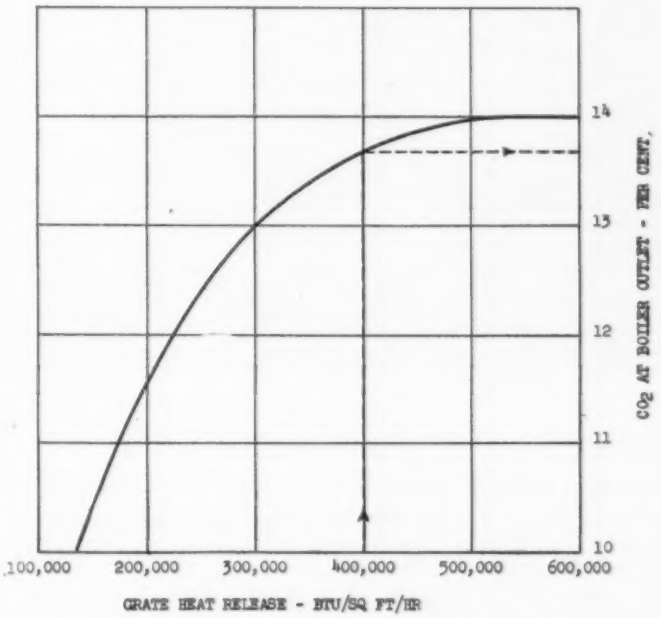

Fig. 6—Grate heat release vs CO_2 at boiler outlet

Likewise, stokers were formerly selected to burn a certain number of pounds of coal, this being a rather easily measured item, so that coal burned per square foot was the logical corollary. With the more complete knowledge now available the steam-generating equipment can be selected on the logical Btu basis, and the grate heat release method therefore completes the cycle for stoker-fired units.

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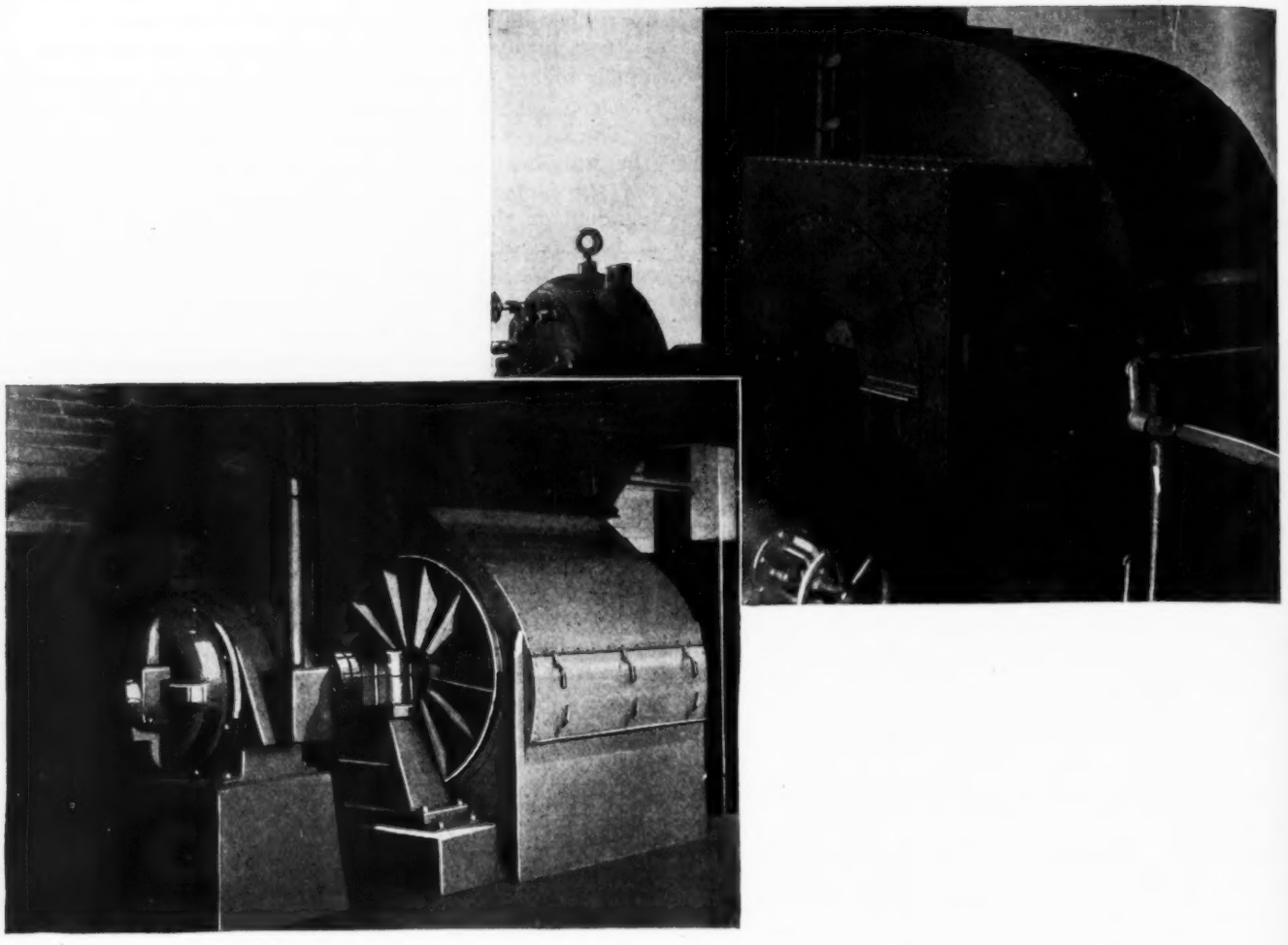

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Engineers Feature Power in Plan for Control of German Industry

This five-point program of the National Engineers Committee is based on a year's study by thirty-five engineering and technological specialists. Control of power generation and distribution is considered basic in destroying Germany's ability to re-arm. The report has been submitted to the State, War and Navy Departments, as well as to the authorities in the American zone of occupation.

IN SEPTEMBER 1944, the presidents of the five national engineering societies submitted a *general* program for the industrial control of post-war Germany. Subsequently, last February, a National Engineers Committee consisting of R. E. McConnell, Chairman; H. S. Rogers, president of Brooklyn Polytechnic Institute; T. F. Barton, vice president of General Electric Company; Col. C. S. Proctor, consulting engineer; Dr. E. R. Weidlein, Director of Mellon Institute of Industrial Research; and Dr. C. E. Williams, Director of Battelle Memorial Institute, was requested by the Engineers Joint Council to make a study and to suggest measures for post-war control of German war potential. The current report, in the preparation of which some thirty-five engineers and technologists cooperated, outlines a *definite* program for control and gives factual and statistical basis for the elimination, prohibition or control of materials essential to re-armament.

Working within the framework of the Yalta and Potsdam agreements, the Committee concluded that assurance that Germany will keep the peace requires the institution and maintenance of effective control of power production and distribution, and industrial plant construction to the end that (1) synthetic fixation of nitrogen be prevented; (2) that production of synthetic liquid fuels be prohibited; (3) the production of aluminum be prohibited; (4) the development or use of atomic energy be rendered impossible; and (5) that the capacities for and production of steel and steel products be limited.

It is also proposed to eliminate danger from secret scientific research by preventing coordination of such effort with development facilities under German control. Economic subsidies to industry by the German government are ruled out as a fruitful source of future war strength.

The report is built around the expressed philosophy that "it is necessary to subtract from aggressor peoples, for a long period of recuperation, the fundamentals of their industrial war potential for armed aggression." At the same time it is held that "complete elimination of German industries, leaving agriculture as the sole occupation, would produce an economic dislocation and social chaos of destructive magnitude, not alone in Germany but throughout Europe."

It is pointed out that adequate enforcement of such complete elimination of industry would be practically impossible, and that such severe restrictions probably would be repudiated by world public opinion in a relatively short time, resulting in a repetition of the aftermath of World War I.

In contrast with this, framers of the engineers' report believe their recommendations would require a minimum of policing and remain effective so long as the policies of control are repeatedly adjusted, with the assistance of competent technical counsel, and adequately enforced by the policing agencies of the United Nations.

Methods of Control Up to Authorities

Recommended controls, the report states, would reduce employment of the total peacetime labor force in Germany by about five per cent, a displacement which should be absorbed easily by re-employment in peacetime agriculture and consumer goods industries.

The report details the industrial factors that must be controlled, supporting its findings with statistics and engineering data, but leaving the determination of the specific methods of control to the authorities charged with that function.

Control must be exerted, the report states, over (1) energy allocation; (2) raw material elimination or limitation, applied to specific elements critical to war industry; (3) processing, fabricating and new construction; (4) scientific research; (5) economic subsidies.

It is recognized that in the field of energy and among the raw materials in German economy, coal stands at the head of the list, supplying 85 per cent of the nation's energy in power and light, as well as providing the raw material base for the huge chemical industry, the synthetic nitrogen industry and the synthetic fuel industry. But because coal is needed in Germany for peacetime as well as war potential industry, the report holds that instead of eliminating the coal industry, it must be controlled by the same body that controls other raw materials. Electric power, likewise, must be controlled at its source, mainly coal.

Even if ample energy were available, modern war would be impossible without a number of products required in large quantities, namely: nitrogen for explosives, aluminum for air power, steel and steel alloys for land and sea warfare, and liquid fuels and lubricants to insure mobility of the instruments of war.

Electric Power

It is recommended that a comprehensive post-war control of German industry be based on a system of

energy allocation. On this subject, the report states:

"The fundamental factor is energy, since it is required in one form or another to operate all processing equipment for the transformation of all raw materials into finished goods. Therefore, regulations based on energy are so inclusive that all industrial operations fall within their scope.

"Control of power distribution through allocation of all coal distribution, while fundamentally effective, would be cumbersome, a handicap to peaceful development and would require a considerable staff. A rigid control of electric power distribution is therefore important to ensure compliance and regulation of German industry.

"The specific details of electric power allocation must be formulated by the Control Council in Germany, possessing first-hand information of the requirements of German industrial and domestic activities. It is assumed that after productive limitations, consistent with the recommendations herein contained, have been determined for German industry, it will be relatively easy to ascertain the energy requirements to supply industrial and domestic needs. All excess capacity above that allotted to a given district, including installations in industrial plants, should be removed and all of the contiguous auxiliaries, building foundations and other services should be removed or destroyed. It should be realized, however, that the electric-power industry in Germany cannot and should not be used as the sole means of controlling other industries for disarmament purposes. Reports on the use of electric energy by individual manufacturing plants cannot be relied upon as a definite indication of the magnitude and nature of manufacturing operations."

Nitrogen Industry

With respect to the German synthetic nitrogen industry, the report recommends:

1. That all synthetic fixed nitrogen production, except cyanamide, within the borders of post-war Germany be eliminated, either by the enforced prohibition of the rebuilding of demolished plants, or the destruction or the removal of any remaining equipment.

That the chemical nitrogen production in post-war Germany be limited to the by-product nitrogen of the permitted steel industry, plus not over 200,000 short tons of nitrogen as cyanamide per year. Electric power allotted to cyanamide production should be controlled accordingly.

2. That all synthetic processes and equipment suitable for hydrogenation of coal or hydrocarbon oils, and for the production of synthetic ammonia, or methanol, and, in addition, any other processes for producing fixed nitrogen by low pressure methods, be eliminated within the borders of post-war Germany, except as has been previously noted.

3. That the total amount of nitrogen allowed Germany through domestic manufacture and controlled import be restricted to the minimum amount necessary for agriculture and such industrial activity as is permitted to continue.

That the available statistics show the consumption of nitrogen by German agriculture for the period of 1924 to 1938 to have averaged 481,000 short tons per year, although the German productive capacity averaged two or three times that amount for the same period. The post-war nitrogen requirement of German agriculture should be determined at appropriate intervals by United Nations soil and fertilizer experts, on the basis of the crops grown.

The needs of Germany for agricultural nitrogen in excess of the recommended domestic production can be supplied in the form of synthetic and natural nitrates from other countries.

Such industrial needs as require anhydrous ammonia, which cannot be advantageously transported overseas, could be supplied from plants outside Germany on the continent.

4. That German citizens, corporations, the German government, or any instrumentality thereof, be prevented from obtaining complete or partial control or any financial interests in any nitrogen fixation plants in any country.

Synthetic Fuels

Concerning synthetic fuels, the report recommends that Germany's synthetic fuel industry be entirely eliminated. It will be unwise to allow any part of the industry to exist, as this would tend to maintain Germany's knowledge and technique of manufacture, and would give a foundation for rapid expansion and conversion to a definite war potential.

Aluminum

In order to allow Germany aluminum only for peacetime uses, the committee would eliminate the manufacture of the metal from raw materials and allow only a light fabricating industry. The recommendations in this respect are as follows:

1. That all alumina producing and smelting plants within the borders of post-war Germany be eliminated, either by demolition or removal in accordance with the recommendation of the Reparations Commission.

2. That importation of bauxite or any alumina ores be prohibited, except for a limited amount to be used as such without smelting, as provided for hereinafter under import regulations (recommendation 8).

3. That the production of petroleum coke and carbon paste be prohibited. The electrical process for smelting aluminum requires about 0.75 lb of carbon for electrodes per pound of aluminum.

4. That the control of energy be studied by competent engineers to determine the practicability of exercising long-term regulation by the rationing of coal to generate power, either as steam or electricity, or exercising instantaneous regulations by control of electricity at central distributing stations. With the elimination of the smelting of bauxite this control would have its most direct application to the fabrication industry.

5. That the aluminum fabrication industry in post-war Germany be restricted to light industry, such as the manufacture of consumer goods. The control in this case may be exercised by limitation of size and type of manufacturing equipment.

6. That a quota for the quantity of aluminum and aluminum scrap to be imported by Germany be determined by competent authorities. It is further recommended that this quota be flexible and subject to periodic review and adjustment by the United Nations Control Council or some division thereof.

7. That aluminum and scrap now stocked in Germany be seized and distributed in accordance with the foregoing plans.

8. That the quantity of alumina used as such and aluminum compounds normally used in peacetime in such industries as the ceramic, manufacturing and chemical be determined and a quota based thereon, and such items be admitted up to this quota without special import license. The total amount of aluminum used in this form is small, and without smelting facilities could not be converted into metallic aluminum.

Control of Atomic Energy Development through Power Regulation

With respect to potential development of atomic power in Germany, the report states:

"It is recognized that the principles of atomic energy may be known to German scientists during the period of the contemplated tenure of these regulations, but it is believed that control of such development will be readily obtained through the rigid regulation of all construction and control of power requirements, to preclude the possibility of construction of plants for the development of such atomic energy."

Steel and Steel Alloys

To limit the war-making possibilities of the steel and steel alloys industry, the report recommends:

1. That the productive iron and steel capacity of post-war Germany be reduced to a level sufficient only for domestic peacetime needs. Definition of this level should be the function of the United Nations Control Council and it should be subject to periodic review by the Council, with such revision as is consistent with the standard of living within Germany.

2. That the importation of iron or iron ore, and alloys or alloy ore be restricted in accordance with the foregoing quota.

3. That the importation of raw materials pertaining to the iron and steel industry, and the manufacture and distribution of the finished goods, be regulated by a "Controlled Materials Plan" such as recommended for the aluminum industry.

4. That the re-equipment of the German steel industry be studied by steel experts of the Control Council for the purpose of eliminating such equipment which, because of its type or size, could, in the opinion of the Council, be converted readily to the production of instruments of war.

5. That all duties, cartel arrangements and state subsidies for steel, or goods and services entering into its manufacture, be prohibited.

Construction Controls

As to the regulation and control of future construction, the report says:

"Evasion of the regulations and controls herein recommended, intended for illegal production of war potential materials, would require large installations, as, for example, facilities for the production of fixed nitrogen, synthetic oil, aluminum, steel and atomic energy.

"Energy controls might be effective for the regulation of established industry, but new plants will be built, and it is therefore necessary to assure that such plants may not be convertible into war plants. Therefore, the rigid control of all new construction should be maintained through the issuance of permits by a Board of Construction Control, composed of experts in all potentials of war production."

Makeup of the Committee

The Executive Committee of the Engineers' Joint Council consists of Malcolm Pirnie, past president American Society of Civil Engineers; Harvey S. Mudd, president, American Institute of Mining and Metallurgical Engineers; Robert M. Gates, past president, American Society of Mechanical Engineers; Charles A. Powel, president, American Institute of Electrical Engineers; and Dr. Lawrence W. Bass, president, American Institute of Chemical Engineers. The combined membership of these engineering societies totals approximately 80,000.

EQUIPMENT SALES

as reported by equipment manufacturers to the Department of Commerce, Bureau of the Census

Boiler Sales

Stationary Power Boilers

	1945 Water Tube		1944 Water Tube		1945 Fire Tube		1944 Fire Tube	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	105	656,593	36	226,537	50	60,710	24	31,701
Feb.	103	496,586	39	256,942	75	99,815	28	43,341
Mar.	135	784,407	47	229,121	77	87,266	44	53,893
Apr.	85	422,213	80	454,175	78	99,154	50	68,430
May	125	812,989	74	392,347	81	83,285	49	66,722
June	185	1,260,550	63	275,450	90	106,085	70	92,621
July	201	1,021,897	78	457,442	88	134,714	56	67,126
Aug.	151	837,018	112	442,766	102	139,436	52	69,832
Jan.–Aug., incl.	‡1,081	‡6,152,230	529	2,734,780	641	810,465	373	493,666

* Includes water wall heating surface.

‡ Includes revised data for January, March, May and June, 1945.

Total steam generating capacity of water tube boilers sold in the period Jan. to Aug (incl.) 1945, 60,484,000 lb per hr; in 1944, 21,622,000 lb per hr.

Marine Boiler Sales

	1945 Water Tube		1944 Water Tube		1945 Scotch		1944 Scotch	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	363	1,542,274	49	273,879	6	1,073	—	—
Feb.	34	178,726	96	507,658	5	1,186	30	9,000
Mar.	69	240,004	70	226,166	10	7,685	38	9,700
Apr.	16	65,252	44	209,906	4	2,126	44	14,405
May	26	110,126	94	443,130	2	526	37	11,100
June	21	114,537	193	1,003,435	22	7,605	32	13,100
July	47	248,664	113	392,704	12	3,352	22	8,120
Aug.	39	133,420	182	811,978	5	1,221	26	11,983
Jan.–Aug., incl.	‡583	‡3,166,895	841	3,868,856	66	24,774	229	77,408

* Includes water wall heating surface.

‡ Includes revised data for January, March, May and June 1945.

Total steam generating capacity of water tube boilers sold in the period Jan. to Aug. (incl.) 1945, 27,736,000 lb per hr; in 1944, 46,902,000 lb per hr.

†Mechanical Stoker Sales

	1945 Water Tube		1944 Water Tube		1945 Fire Tube		1944 Fire Tube	
	No.	Hp	No.	Hp	No.	Hp	No.	Hp
Jan.	43	19,423	35	13,982	185	24,899	149	20,961
Feb.	57	22,510	34	18,437	162	20,565	158	22,655
Mar.	108	39,801	125	52,547	236	32,447	457	66,500
Apr.	59	21,604	194	79,008	198	27,438	640	92,338
May	102	40,977	248	99,928	245	33,072	865	123,155
June	78	33,644	57	21,055	250	34,463	295	35,952
July	160	71,025	80	28,543	264	34,230	290	41,910
Aug.	90	39,159	115	35,077	341	41,763	359	48,612
Jan.–Aug., incl.	697	288,143	888	348,577	1,881	218,877	3,213	452,083

† Capacity over 300 lb of coal per hour.

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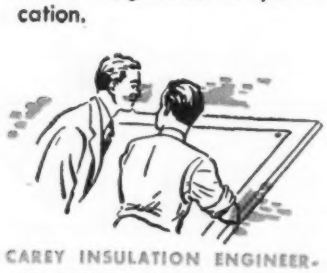

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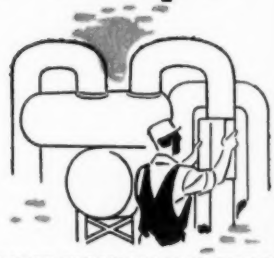

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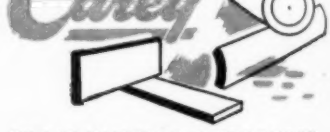

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Court Decisions Involving Engineering

By LEO. T. PARKER

Attorney at Law, Cincinnati, O.

A review of selected higher court decisions of recent months concerning enforcement of city ordinances, fair labor standards, liability for injuries sustained and admission of evidence; all having to do with the location, use, and operation of power equipment.

SELDOM have the higher courts rendered so many interesting and informative decisions involving power engineering as have been given during recent months. It is important that readers know the cause and outcome of such lawsuits, and the information should assist in avoiding similar legal controversies; also, these new citations are valuable when defending unavoidable suits. Those who desire all details of any of these decisions may, by referring to a specific citation, obtain and read the complete case in any good library.

Plant Manager Not User

Generally speaking, city ordinances require "users" of plants to employ licensed engineers to operate steam boilers. According to a late higher court decision a plant manager is not a "user." Moreover, such ordinances cannot be avoided by plant owners on mere technicalities.

For illustration, in *City of St. Louis v. Consolidated Products Company, 185 S. W. (2d) 344*, reported April, 1945, it was shown that a city ordinance provides that the "owners and users" of steam boilers and engines of a capacity of over seventy-five (75) square feet of heating surface and steam pressure of over twenty-five (25) pounds of steam to the square inch, must employ an engineer licensed by the Board of Engineers of the city to operate and be in charge of the boiler and engine.

A company which operates a plant, for the purpose of producing animal feed by processing condensed buttermilk, owned and operated a steam boiler and two pumps. One of these pumps fed water to the boiler and was driven by an electric motor; the other created a vacuum in a pan, and was used in processing the company's product. This latter pump was driven by steam generated in the boiler. The witnesses for the city testified that the mechanism was an engine; while the company's witness testified that it was not an engine, but merely a pump.

Anyway the lower court convicted both the company and the plant manager of violating the ordinance because the plant manager himself actually took care of the boiler and did everything necessary to cause it to operate. The company appealed to the higher court.

In holding the company guilty of violating the ordinance, this higher court said:

"In our opinion, it is obvious that the purpose and intent of the lawmakers in enacting the ordinance in question was to promote the safety and welfare of the community by requiring that steam boilers be under the charge of qualified persons, regardless of whether engines were operated in conjunction with them or not."

However, the higher court reversed the lower court which also convicted the plant manager of violating the ordinance. This court said:

"The boiler in question was owned by Consolidated Products Company. Rolfmeyer was the plant manager of Consolidated Products Company, and although he took care of the boiler and performed all of the services necessary to make it operate, we do not think he was a 'user' within the meaning of the ordinance."

License Law Void

It is well settled that all taxation and license laws are void and unconstitutional which are so incomplete that such statute leaves to a ministerial officer the application of the law. In other words, such a law is invalid as an unwarranted and void delegation of legislative power to an administrative officer.

For illustration, in *Krebs v. Thompson, 56 N. E. (2d) 761*, reported November, 1944, it was shown that a state legislature passed a law "to regulate and license the practice of professional engineering." The law was incomplete in many respects, and its application was left to certain state officials.

The higher court held the law void because it was so incomplete and uncertain that men of ordinary intelligence "must necessarily guess at their meaning and differ as to their application," and also because the law delegated to the Department of Registration and Education the power to determine whether a person who renders any service involving the application of engineering principles and data shall be required to secure a license. This court said:

"The words 'engineering principles and data' are not defined in the act. They have no fixed and definite meaning. . . . Statutes which are so incomplete, vague, indefinite and uncertain that men of ordinary intelligence must necessarily guess at their meaning and differ as to their application, have uniformly been declared unconstitutional as denying due process."

Prime Movers and Emergency

Considerable discussion has arisen from time to time over the question: What is the legal interpretation of a state law which exempts from license and other taxation steam engines classified as "prime movers" and "emergency" purposes? This question is clearly answered by a recent higher court.

For example, in *State v. Getty, 20 So. (2d) 546*, reported February, 1945, it was shown that a state law provided that users of mechanical power of more than ten horsepower shall be subject to the payment of an excise, license or privilege tax of fifty cents (50 cents) per annum for each horsepower capacity of the machinery or apparatus, known as the "prime mover" or "prime movers." This law further specified that the tax is *not* applicable to machinery and apparatus used for "standby or emergency" purposes. In other words, this state law imposed the tax only on "prime movers," and then expressly provides that the tax shall not apply to "machinery and apparatus used for standby or emergency purposes."

A company which pumped oil from six wells had a small steam engine stationed at each of the wells. There was, however, only one boiler used for generating steam to operate all six of these engines, and it was so located that all of these engines are connected with and may be operated from the one boiler.

Testimony showed that these steam engines so stationed, as likewise the boiler, are never used for pumping the wells. All of the wells are pumped by electric power. These steam engines are used for the sole purpose of pulling the pipe in a well; to pull the pumps in the wells when they need repairs; to pull sucker rods when worn or broken and have to be replaced; or when some other breakdown or trouble occurs or something goes wrong with a well.

The state sued to recover payment of license fees, or taxes, on these engines. The higher court refused to order payment of the taxes and said:

"This court, therefore, is clearly of the opinion, that the steam engines and-or boiler in this case upon which the power tax is sought to be imposed, is not subject to this tax: (1) for the reason that these engines are not 'prime movers' used in the conduct of the defendants' business within the contemplation of this statute, and (2) for the reason that they come within the provision of the cited Power Tax Statute which expressly provides 'that the tax imposed by this section shall not apply to machinery and apparatus used for standby or emergency purposes.'"

Fair Labor Standards Act

The Fair Labor Standards Act is applicable to employees who process, or handle merchandise in interstate commerce. This law provides that a work week shall consist of forty hours between certain dates and forty-two hours between certain other dates. The law also provides that if an employer fails to pay an employee time and one-half for overtime, such employer shall pay the employee *double* the wages due, plus attorney's fees.

It is important to know, however, that a higher court has held that an employee, who sues his employer, must prove positively that he worked *more* than the maximum hours in any week. His failure to prove these facts entitles the employer to a favorable verdict.

For instance, in *Stewart v. Mabee Company, 147 Pac. (2d) 731,* it was disclosed that an employee sued his employer for back wages, overtime, and lawyer's fees under the Fair Labor Standards Act.

Since the employee *failed to prove* when he worked the alleged overtime, and how many extra hours he had worked, the higher court refused to hold the employer liable. This court said:

"It has been said many times that in order for a plaintiff (employee) to recover under the Fair Labor Standards Act he must prove his case with reasonable certainty."

Zoning Ordinance

It is well-established law that a new city zoning ordinance cannot be used to prohibit operation of power plants already in operation in the zoned section. However, neither a new nor an old established company may install new equipment which, at the time of installation, violates any ordinance.

For example, in *National Company v. Ponzio, 42 Atl. (2d) 753,* reported August, 1945, it was disclosed that a manufacturing company was located in the same locality and section of a municipality for 10 years. Also, it had operated a small 5-hp engine in its business.

The municipality enacted an ordinance which classified the section in which the company was situated as "A," residence zone. After enaction of this ordinance the company installed machinery which used a 15-hp engine and, thereby, violated the ordinance.

In the subsequent suit by the municipality to stop operation of the new engine the officials of the company argued that its operation was necessary to the company's extended and increased business. Also, they proved that other factories are now located in this section of the city, and that they have for many years used engines of more than 15 hp. However, the city court refused to permit the company to operate the new equipment, saying:

"True there are two paper mills and two railroads in the immediate vicinity of prosecutor's yard. They were unquestionably in existence and in use prior to the adoption of the zoning ordinance."

Engineer Injured by Automobile

Considerable discussion has arisen from time to time over the legal question: When is an employee entitled to payment of compensation for injuries received when he is off his employer's premises? A review of one late higher court decision which illustrates a phase of the law on this subject is of interest.

For example, in *Payne & Dolan v. Industrial Commission, 46 N. E. (2d) 925,* the testimony disclosed facts, as follows: A person named Jorsch was employed as engineer in an asphalt plant. His hours were from 2:00 p.m. to 10:00 p.m. He traveled to and from his work by public bus, which passed the plant. On going to work he got off the bus directly in front of the plant and went to his work over a driveway leading from the slab on the highway into the premises where he was employed. At night he came out over this same driveway, crossed over the pavement and took a north-bound bus.

One night Jorsch took a wrench and his flashlight and walked down the gravel driveway to catch the bus. He testified that he stopped as he approached the highway and looked both ways but saw nothing; that he remembered he got up close to the edge of the pavement but he didn't remember anything after that. He didn't know an automobile had struck him until the next day.

Jorsch sued his employer to recover compensation under the State Workmen's Compensation Act. He contended that he was entitled to compensation, although he was injured after his regular working hours. The contention was based upon the fact that he had no means of going to and from his work except by bus across this driveway extending into his employer's premises.

In holding Jorsch *not* entitled to compensation, the higher court said:

"The test is whether the employee, when injured, was at a place where, by reason of his employment, he was required to be by reason of his employment. If his work for the day is ended and he is at a place off the employer's premises, where the hazard to which he is exposed is the same and of the same degree as that to which the public is exposed, his injury is *not* compensable."

Service Employee Burned to Death

No ordinary employee is entitled to recover damages or compensation for an injury *not* sustained "while working" within the scope of the employment. However, "service" men are different in the eyes of the law if they are subject to call by their employers. See *Souza's Case, 55 N. E. (2d) 611,* reported August, 1944, where it was shown that an employee lost his life in a fire while asleep in a rooming house.

The employee's work as a power plant service man called him to various places and required him from time to time to be away from home nights. He was required to work whenever he was called upon to repair equipment in power plants. In any emergency, whether during or after regular hours, he was expected to put in as much of his time and attention as in his judgment the situation required. He had no stated or definite hours of work each day. In the event of necessity or emergency he was subject to the company's call at any time. In other words, his employment was "of a continuous nature." He was paid a salary and, in addition, when away from home, he was paid his expenses for room, board and transportation.

In view of this testimony the higher court held the employee's dependents entitled to receive payments of compensation under the State Workmen's Compensation Act. The court held that the employee was within the scope of his employment when he was burned to death in the lodging house.

This decision would tend to establish law that an employee is entitled to compensation, although not engaged in the actual performance of work at the moment.

City Sells Power Plant

Higher courts consistently hold that the terms "materials," "supplies," etc., include electric current, water or gas, which requires municipalities to comply with state laws specifying that purchase must be made from "lowest bidder." For illustration, in *Mullen v. Town of Louisburg, 33 S. E. (2d) 484,* reported June, 1945, it was shown that a state law provides that no county or city shall purchase materials or equipment requiring an expenditure in excess of $1000, unless the proposition is presented to various bidders.

For many years citizens have advocated a change in the power used to operate its water plant. Recently, the city council passed an ordinance granting a power company a franchise to use its streets. Moreover, the city officials gave *public notice* that it would offer its engines for sale at public auction to the highest bidder. Although a citizen instituted suit to restrain the sale of the engines, the higher court approved the sale, saying:

". . . The better reason dictates the conclusion that the statute applies *only* to contracts in relation to supplies and materials where the bidders have the right to name the price for which they are willing to furnish the same."

Slight Evidence

An important point of law, recognized by higher courts, is that the "slightest" evidence may result in an injured engineer being entitled to compensation for an injury. In a late case, the court held that the mere fact that an engineer "told" a night watchman that he "fell" resulted in his dependents being awarded compensation.

For instance, in *Schmitt v. Doeh Casting Company, 58 N. E. (2d) 224,* it was shown that a person named Schmitt was employed as a night engineer and worked alone. One night he told the night watchman, whom he found in the dispensary, that he had fallen. Schmitt made no further mention of his accident until a week later when he went to the company's nurse who made and recorded on Schmitt's card the following:

"10-7-38 states that 10-2-38—12 a.m. slipped and fell across a pipe which was about 1 ft off floor. R. chest hit pipe. Last night noticed R. chest getting sore. Pain when taking deep breath. Pyrasin. See Dr. S. tomorrow. Reported accident to Steve, the night watchman."

Several weeks later Schmitt died and his dependents sued to recover compensation under the State Workmen's Compensation Act.

The lower court refused to allow compensation but the higher court reversed the verdict, saying:

"The oral statement to the watchman and the written dispensary record being essential facts basic to the hypothetical question, they should have been received in evidence to determine whether such injury was the proximate cause of death."

Law on Watchmen

Either day or night watchmen may or may not be within provisions of the Fair

Labor Standards Act, depending upon his duties.

In *S. H. Robinson & Company, Inc., v. Larue, Tennessee, 156 S. W. (2nd) 359*, it was shown that a night watchman kept up fires in boilers in a plant which manufactured products shipped in interstate commerce. This court said:

". . . Where a night watchman has to perform other duties, such as keeping up steam in the boilers, he is classified as an employee engaged in interstate commerce."

Also, see *Martin v. Graham Company, 176 S. W. (2d) 843*, where it was shown that a night watchman watched motor vehicles in the yard at night to prevent thieves from molesting them. He opened and shut the yard gates for trucks which hauled goods in interstate commerce. Also, he fired the boilers at night.

This employee sued to recover $1474.70 which represented time and one-half for the hours he had worked each week over 40 hr, and also the difference between the hourly wages he was paid and wages specified by the Fair Labor Standards Act. The higher court held in favor of the employee, and said:

"There was ample evidence upon which to base a finding that plaintiff's (employee's) wages and hours were governed by the Act."

In this case the higher court explained that the acts of the watchman in opening and shutting the yard gates to allow trucks used in *interstate* commerce to pass, and the firing of boilers classified him an interstate employee.

And again in *Hart v. Gregory, 10 S. E. (2d) 644*, it was shown that an employee was hired as a night watchman and, also, to keep the boilers filled with water. It was necessary that these boilers be kept full of water during the night time. He sued the company to recover $1153, the difference between the wages he actually had received and the wages he should have received under the Fair Labor Standards Act.

The lower court refused to hold the employer liable but the higher court reversed this verdict and explained that when a watchman attends to boilers he must be paid wages specified by the Fair Labor Standard Act.

On the other hand, see *Southern Corporation v. Walton, 11 So. (2d) 912*, where it was shown that a night watchman performed no service other than making hourly round of the plant at night. The higher court held the watchman not within the Fair Labor Standards Act.

Small Manufacturers Support Patent System

Plans for a counter-offensive against widely publicized attacks on the U. S. Patent System are being made up by a nation-wide group of small manufacturers, representing twenty-eight classes of industries. This new organization, incorporated as the National Patent Council, will have headquarters in Gary, Ind., and offices in New York and on the Pacific Coast. According to J. W. Anderson, president of The Anderson Company of Gary, Ind., who is heading the movement:

"Although the vociferous critics of the Patent System profess to be saving the country from monopoly, they are in reality promoting monopoly by threatening the life of every small company relying upon patents. Small manufacturers originate and produce most of the patented inventions upon which industry is based, and so long as Congress and the courts maintain inviolate the traditional 17-yr exclusive right of the inventor to his own creation, the smaller manufacturers can continue to invade successfully the markets of entrenched competitors."

Seeks to Curb Discretion of NLRB with Regard to Engineers

The American Association of Engineers is circulating a petition to engineers and technologists, which it is planned to submit to the Senate Committee on Education and Labor, seeking amendment of the Wagner Labor Relations Act. It is contended that the Act as now written and administered tends to amalgamate professional workers in a "labor front," merging engineers, architects, chemists and other technologists in units represented by heterogeneous labor unions that are committed to bargaining methods and objectives entirely inconsistent with principles of professional conduct. These conclusions are based on some eight years' systematic observation of the operation of the Act.

The Association recommends that Congress provide for a complete and detailed classification of all positions in the fields of technology and related mechanical arts, crafts and trades which constitute industrial science, in order to establish a clear statutory line of demarcation between technologists and technicians—that is, between professional and non-professional workers. Also, that it issue a clear directive to the National Labor Relations Board requiring the latter to permit all technologists (as officially determined by the classification) to either waive or exercise rights of self-organization and designation of representatives in fully autonomous units, restricted to and controlled by technologists.

As a body, the American Association of Engineers takes no position with regard to the provision of the pending bill, S.1171, introduced by Senators Ball, Burton and Hatch, for amendment of the Wagner Act. It feels, however, that with recessions in production, the competition from the untrained and ill-trained, unless checked, will jeopardize the economic status of technological employees, and that under present administrative practice of the Wagner Act professional engineers will be amalgamated in a "labor front" in which they will be helpless minorities. The motive is to curb the discretion of the National Labor Relations Board which now has full and practically final authority to decide who is a professional worker and how he shall be disposed in bargaining units. The situation is regarded as most urgent; hence the petition which is being circulated not alone to members of the Association but to engineers generally.

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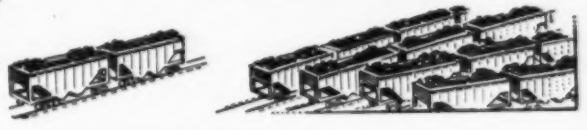

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A 10,000-Kw Gas Turbine Set

IN VIEW of the present activity in gas-turbine development in the United States, the following excerpts from *The Brown Boveri Review*,[1] concerning a 10,000-kw stationary unit under construction in Switzerland for installation in Southeast Europe, are of special interest.

This unit is intended for peak load and standby service on an interconnected system comprising both steam and hydro stations. The fuel is natural gas, which being relatively cheap did not justify the most economical installation. Although a two-stage turbine was chosen, the recuperator was omitted. Hence the calculated efficiency with a gas temperature of 1112 F was only 21.5 per cent, referred to output at the generator terminals. With a recuperator of 4.3 sq ft of surface per kilowatt of useful power, it would have been possible to attain 30 per cent efficiency; but the increased cost of plant would not have been justified.

The two-stage combustion turbine consists of two gas-turbine sets connected in series on the gas side. The high-pressure turbine drives the second-stage compressor and the low-pressure turbine drives both the low-pressure compressor and the generator. The speed of this set therefore remains constant, while that of the high-pressure compressor varies with the load.

[1] Vol. XXXII, Nos. 1 and 2.

There are two combustion chambers, the second being placed between the high-pressure and the low-pressure turbines. In this second combustion chamber the exhaust gases of the first turbine, which contains a considerable amount of excess air, are again heated to the initial temperature by means of additional fuel. In order to reduce the power required to drive the compressor, the air is cooled between the two compressors.

Components of Set

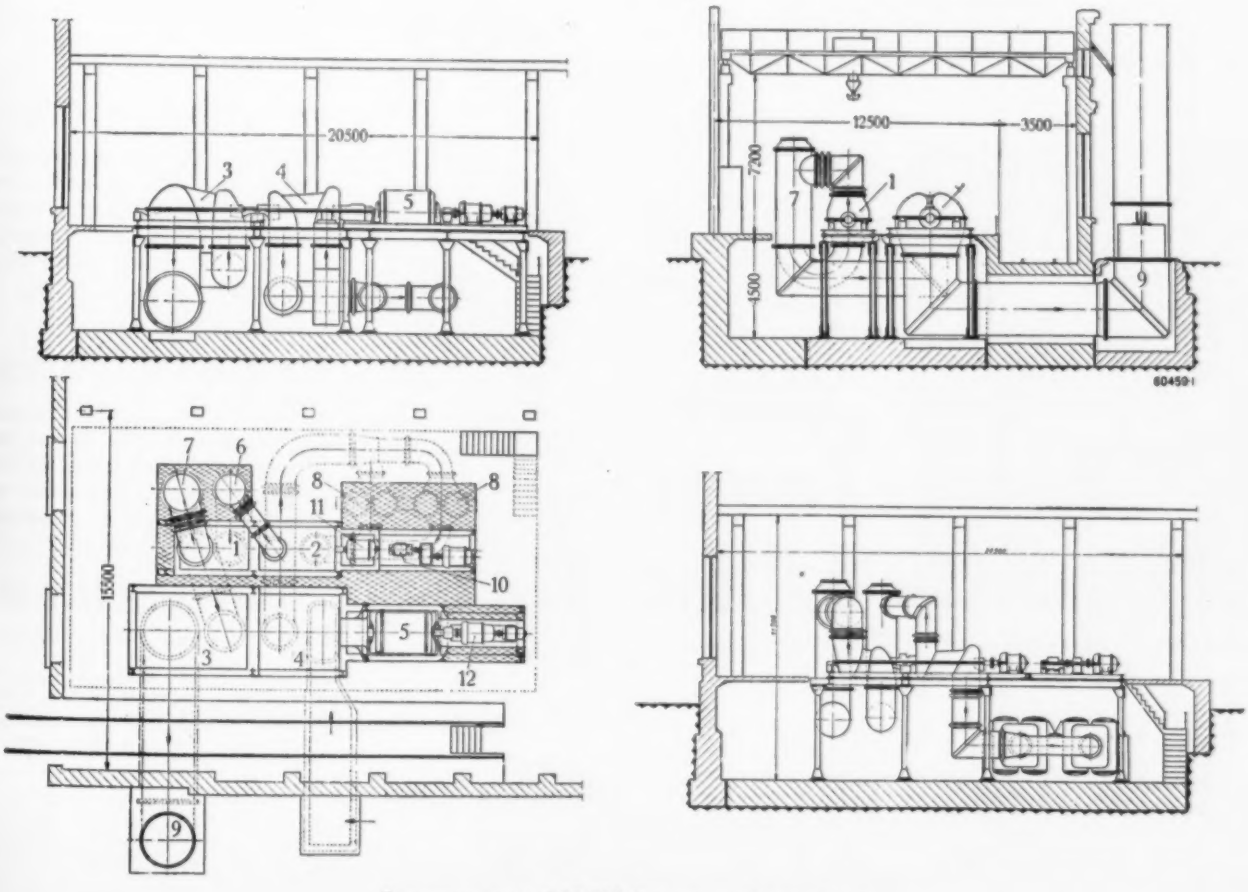
Referring to the accompanying arrangement drawings, (*1*) is the high-pressure turbine with the high-pressure compressor (*2*) and the low-pressure turbine (*3*) with the low-pressure compressor (*4*), as well as the generator (*5*) supplying the useful power. The driving gas is produced in the combustion chamber (*6*) and is reheated to the original temperature in the combustion chamber (*7*), which is placed between the high-pressure and low-pressure turbines. Between the high-pressure and low-pressure compressors there is a cooler (*8*) for cooling the compressed air. The exhaust gases of the low-pressure turbine discharge directly to the atmosphere at (*9*). The natural gas is compressed by the compressor (*10*) to the pressure in the first compressor chamber. The pressure at which the gas is supplied is sufficient for the second combustion chamber. The two sets are started by means of the starting motors (*11*) and (*12*).

About 660,000 lb of air per hour are required for a useful output of 10,000 kw. The air is compressed to approximately 43 psi abs in the first compressor and to 170 psi abs in the second, the power taken by the two compressors being 14,500 kw and 11,000 kw, respectively.

The amount of cooling water required is relatively small, compared with a steam turbine plant of like capacity. Altogether, about 1300 gpm is circulated in the cooling towers. A small part of this compensates for the evaporation losses.

Both sets are provided with motors for starting. These are capable of bringing each set up to 20 per cent full-load speed, after which the turbines accelerate themselves to full speed. It is estimated that the time required from starting until full speed is reached will be about 10 minutes.

Commenting upon the importance of a recuperator for gas-turbine plants where high efficiencies are desired, the article states that in order to obtain an efficiency comparable with best steam-turbine practice, about 4.3 sq ft of heater surface are required in the case of two-stage gas turbines and about $10^1/_2$ sq ft in the case of single-stage sets. Because of the large size of such recuperators they have been designed for out-of-doors installation at the base of the stack or in a walled duct that serves as a passage for the gases below the turbine-room floor.



Arrangement of 10,000-kw gas-turbine plant

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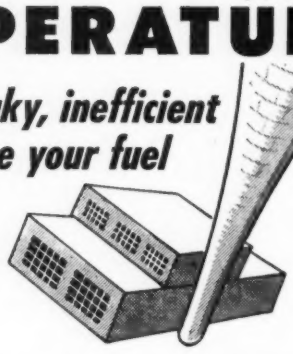

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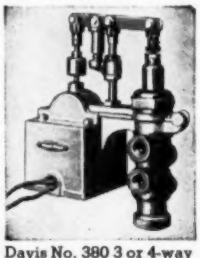

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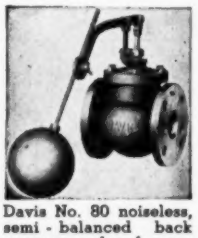

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Analysis of Ash from U. S. Coals

TECHNICAL Paper 679 by W. A. Selvig and F. H. Gibson of the Bureau of Mines has just been released, containing numerous tables giving the analyses and fusibility of ash from various coals of the United States. Ash-fusion temperatures are included for many of the coals. The authors comment, in part, as follows:

Coal ash is comprised chiefly of compounds of silicon, aluminum, iron and calcium, with smaller amounts of magnesium, titanium, sodium and potassium. Although these constituents are reported as oxides by the analyst, they occur in ash as a mixture of silicates, oxides and sulfates, together with small quantities of phosphates and other compounds. The composition of ash from different coals varies widely, depending on the quantities of clay, shale, pyrite, calcite and other minerals.

The principal source of the iron oxide shown in the analyses is pyrite, which is one of the most commonly occurring mineral impurities in coal. Sulfur combined with iron in the form of the mineral pyrite or marcasite is known as pyritic sulfur. Two other forms of sulfur are recognized as occurring in coal. These are organic sulfur, which is sulfur combined with the coal substance, and small amounts of sulfate sulfur in the form of calcium sulfate or iron sulfate. According to investigations by Yancey and Fraser, the percentage of pyritic sulfur varies widely and the organic sulfur is distributed more uniformly. Sulfur in the form of sulfates in freshly mined coal is generally very small in amount, many coals containing 0.05 per cent or less.

The sulfur trioxide reported in the coal-ash analyses represents sulfur retained in the ash, principally as calcium sulfate resulting from interaction between calcite, pyrite and oxygen. Ash from coals high in calcite and pyrite is high in SO_3, and it has been found that the quantity of SO_3 retained in the ash of such coals varies according to the heating procedure used in ashing the coal. Lower ash and lower sulfur in the ash are obtained by slow rates of heating because under these conditions less of the SO_3 is fixed in the ash as calcium sulfate. As the SO_3 is evolved during the melting of coal ash and has no apparent effect on ash fusibility, it is customary to calculate ash analyses to a sulfur trioxide-free basis when relating ash composition to ash fusibility.

Two classes of ash-forming mineral matter generally recognized as occurring in coal are *inherent mineral matter* and *extraneous mineral matter*.

The inherent mineral matter may be considered as that portion which is organically combined with the coal. Little is known about this form of mineral matter because it cannot be detected by the petrographic microscope. It contains chemical elements such as iron, phosphorus, sulfur, calcium, potassium and magnesium, that have been assimilated by the living plants. Other elements, such as silicon, sodium, manganese and aluminum, are formed in many plants, although not generally considered essential to plant growth.

Some mines in eastern Kentucky have produced lump sizes of coal containing less than 1.5 per cent ash.

Extraneous mineral matter in coal may be defined as that which is foreign to the plant material contributing to the formation of the coal. It is considered to consist of mineral deposited contemporaneously with the plant from which the coal was formed, or those deposited in cleavage and fracture cracks after the peat had been consolidated. Ordinarily a large proportion of the ash in coal as mined is derived from extraneous matter.

Since mineral matter is not distributed uniformly through coal, variations frequently occur in the composition of ash from coal in different parts of the same bed.

Analyses of 194 samples of ash of coals from 20 states and Alaska are tabulated in the report. These show a wide variation in the composition of the ash of which the following limits are typical:

Silica (SiO_2)	20–60 per cent
Aluminum oxide (Al_2O_3)	10–35 per cent
Ferric oxide (Fe_2O_3)	5–35 per cent
Calcium oxide (CaO)	1–20 per cent
Magnesium oxide (MgO)	0.3–4 per cent
Titanium oxide (TiO_2)	0.5–2.5 per cent
Alkalies (Na_2O and K_2O)	1–4 per cent
Sulfur trioxide (SO_3)	0.1–12 per cent

It is pointed out that, in general, it is difficult to establish definite relationships between coal-ash composition and softening temperatures, as determined in the laboratory, because coal ash is a complex mixture of many constituents.

WPB Releasing Power Men

Specialists in power and power plants serving the War Production Board are now available to private industry, it is announced by John A. Warner, Director of Region 2, consisting of New York State and northern New Jersey.

"The end of the war," Mr. Warner states, "has terminated many of the Board's activities, thus making possible the release of these specialists who have unselfishly remained with the Board until their tasks were completed, even though many had opportunities to return to private industry months ago at considerably increased compensation."

It is emphasized that the personnel now available have had repeated contacts with many trades and businesses during their association with the Board, thus expanding their knowledge of industry as a whole. "Moreover," Mr. Warner adds, "these men and women have mastered the technique of cooperation between business and government. Such an asset will become increasingly valuable to any firm, particularly during the reconversion period."

Employers desiring to interview power and power plant specialists are invited to write to the Regional Director, War Production Board, Empire State Building, New York 1, N. Y., or telephone Murray Hill 3-6800, Extension 700.

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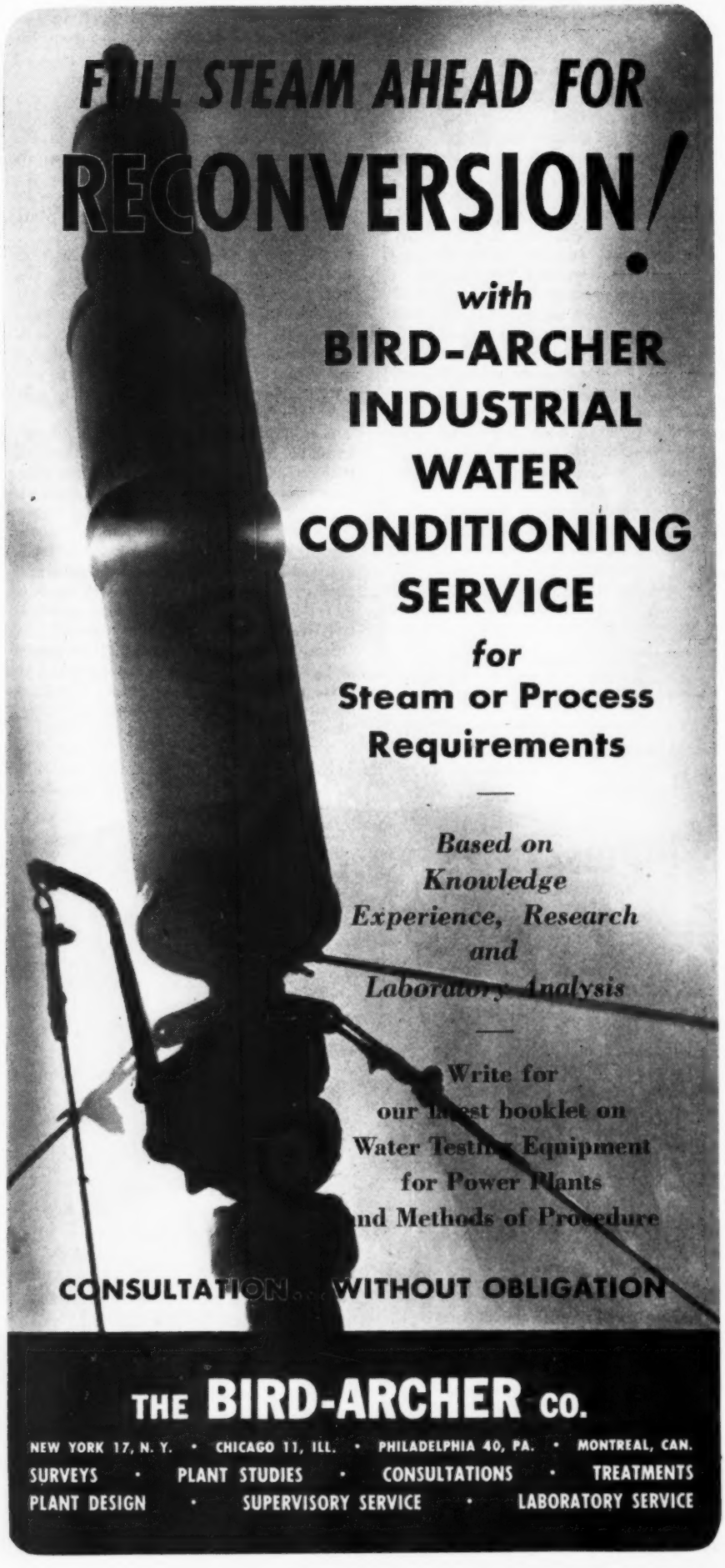


$2,500,000 for Post-War Collegiate Research

Scientists who made the atomic bomb, radar, and a host of other vital war weapons will have a chance to return promptly to college laboratories for scientific research and teaching through $2,500,000 in grants offered to educational institutions by Research Corporation, of New York, a non-profit organization devoted to advancing research and technology by use of revenues from inventions assigned to it by public-spirited inventors.

Preference in making these grants will be given, other factors being equal, to smaller institutions and those of more limited financial resources for research.

The five-year program announced by Dr. Joseph W. Barker, acting president, who has returned to his duties with the Corporation and with Columbia University from service as Special Assistant to the Secretary of the Navy, will result in 100 to 200 grants of $2500 to $5000 each year in order that talented young scientists, engaged for the most part in war research, in uniform or as civilians, will be able to undertake at universities and colleges research of peacetime importance in pure science, especially chemistry, physics, mathematics and engineering.

The first grants will be made in a few weeks by a special committee of eminent scientists from industrial and university laboratories. The committee is composed of Acting President Barker, who is also Dean of Engineering at Columbia University; Dr. Thomas H. Chilton, director of engineering for duPont; Dr. William D. Coolidge, X-ray consultant for General Electric Co.; Timothy E. Shea, manufacturing engineer of Western Electric Co.; Dr. Lloyd P. Smith, associate research director of Radio Corporation of America; Col. Stafford L. Warren, Professor of Medicine at the University of Rochester; and Dr. Robert R. Williams, inventor of the synthesis of vitamin B_1 and coordinator of research of Research Corporation.

Grants will be made to the institutions at which the scientists will work and teach. The funds allotted will be available for the purchase of needed equipment and for employment of assistants either as fellows or otherwise. Awards will be based primarily upon the demonstrated ability of the men who will conduct the researches and contribute to the teaching program of the school.

Scientists For Next Generation

"For the past four or five years," said Dr. Barker, "the Government, through the Office of Scientific Research and Development, the National Defense Research Council, the Army, the Navy, and the Air Force, has supported a vast research and development program into which has been drawn the great majority of the most competent university research men. Already the demobilization of these research projects is under way. When their war jobs are finished many of these talented young scientists should be going back to college laboratories and lecture rooms to train and inspire the next generation of science.

"War conditions have greatly disturbed our educational institutions by diversion

of talented members of their faculties into war research, by drawing off faculty and students into military service, by utilizing educational facilities for military service training programs and by interrupting sources of financial support.

"Research budgets have been drastically curtailed, especially in the smaller institutions, which in many cases have not had opportunity to undertake Government research on a substantial scale. The financial strength of many institutions also was impaired by the depression and the war conditions which followed. Now new burdens are thrust upon them as young men from the services return to resume their interrupted training.

"Research Corporation's program of special post-war grants will round out the plans that are being made for the most effective and most prompt return of the war-engaged scientists to peacetime fundamental and applied research, and will assist colleges in building research-minded staffs."

Grants Made from Patent Revenues

Research Corporation was begun in 1912 with the gift, through Dr. F. G. Cottrell, of patent rights on electrical precipitation, which is used for removing dust, fume and mists from industrial gases and from the atmosphere. From revenues derived from these and other patents it has made grants of $1,279,637 in past years to 52 institutions.

Gas-Turbine Laboratory at M.I.T.

Gifts totaling half a million dollars for establishing a gas-turbine laboratory at the Massachusetts Institute of Technology for graduate instruction and fundamental research in this new and promising field of engineering, have been announced by Dr. Jerome C. Hunsaker, head of the departments of aeronautical and mechanical engineering.

Recent advances in gas-turbine design indicate significant possibilities for the future and emphasize the need for specialized technical studies and the discovery of new techniques required in the construction of machines operating at extremely high speed, high temperature and high compression. The Institute's new laboratory, which is to be completed as soon as possible, will undertake such a program. Its equipment will include a supersonic wind tunnel and unique facilities for research on the elements of compressors, combustion devices, jets and gas turbines. Test facilities will also be provided for the operation under controlled conditions of such devices.

In announcing plans for the turbine laboratory, Dr. Hunsaker said:

"Recognizing the importance of the field and the need for immediate work both in research and in the training of young engineers, the Institute established a faculty committee representing aeronautical, mechanical, metallurgical and chemical engineers to investigate the present status and future potentialities of gas turbines. The report of that committee was emphatic on one point, that the gas-turbine field must be recognized as one of the most important objects of study in mechanical engineering.

"Because gas-turbine design problems embody the entire range of mechanical engineering science, the subject can also be a focus for research in the aerodynamics of the flow of gases under compression, including the design of variable jets, combustion, materials to resist high temperatures and many other topics."

Model of Montaup Boiler

The cover photograph of this issue shows a recently completed scale model of the well-known 650,000-lb per hr 1800-psi C-E Controlled Forced-Circulation Steam-Generating Unit installed at the Somerset Station of the Montaup Electric Company, Somerset, Mass., engineered by Stone & Webster.

This model, constructed of aluminum and occupying a space approximately $3\frac{1}{2} \times 2\frac{1}{2} \times 3\frac{1}{2}$ feet, required about 7000 man-hours plus 2000 supervisory hours to build. Being an exact replica of the original unit which involves over 22 miles of tubing, the model contains over a mile of tubes, the fabrication of which required special tools, particularly with reference to the bifurcated fin tubes of very small diameter. A special machine was also built to roll the nipples and tubes in the drums and headers. This entered the drum before the head was put on and rolled every tube without being taken out. The headers were rolled through the handholes. The numerous bends required a special machine.

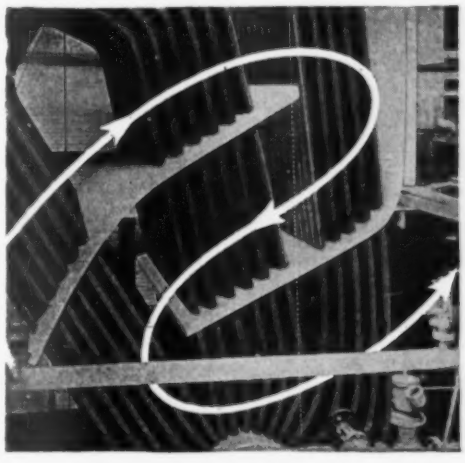
The model was made by Mr. E. C. Keithley of Combustion Engineering Company, who has constructed many other models of C-E stationary and marine boilers, including one of the million pound per hour high-pressure Ford units, which it will be recalled was exhibited at the New York World's Fair and which is now on permanent exhibit at the Ford River Rouge Plant. All these models have been constructed in the basement workshop of Mr. Keithley's residence in Detroit.

It is expected that the model of the Montaup unit, now in the reception room of the Combustion Engineering Company Office, will be on view during the forthcoming A.S.M.E. Annual Meeting in New York at which a panel session on operating experience with this unit is scheduled.

Coal Planer Employed by Germans

A new type of coal-mining machine, known as a "coal planer," together with plentiful slave labor, enabled the Nazis to meet their wartime coal needs and continue to export to satellite countries. This has been revealed by a representative of the Bureau of Mines sent overseas to study the European mining situation.

The coal planer, which has a manganese-steel cutting blade, employs the same principle as the ordinary wood plane and takes a 12-in. slice from the lower third of the seam. The upper two-thirds cave over the planer and into automatic loading troughs.



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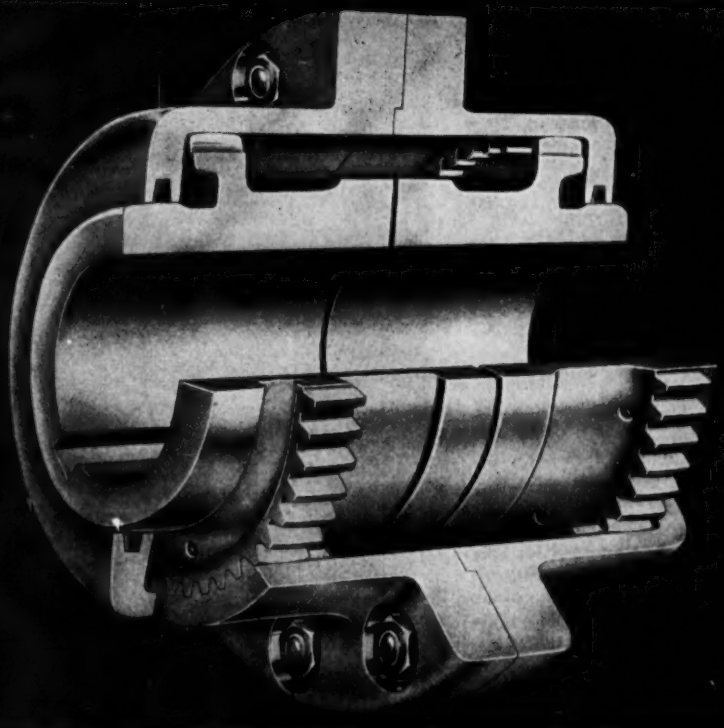

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NEW CATALOGS AND BULLETINS

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Gas Analysis Apparatus

Burrell Technical Supply Company has recently published a new 96-page book, "Burrell Gas Analysis Apparatus and Burrell Manual Gas Analysts—Catalog 80." The Catalog section comprises half the book and is exceedingly well organized and illustrated. The Manual for Gas Analysts is devoted to the volumetric method, describing technique and apparatus in sufficient detail to provide the inexperienced analyst with adequate working knowledge. The book also contains a bibliography and a general index.

Useful Shaft Data

De Laval Steam Turbine Company has published a 16-page booklet of handy data and short cuts which should be a great time saver for anyone whose work involves determination of required shaft sizes. It includes tables, curves and formulas for computing torque, deflection angle of thrust, bending moment, and other factors in solid, hollow, keywayed and stepped shafts. Complimentary copies may be had by writing on your business letterhead.

Pneumatic Transmission

A new 28-page Data Book No. 1000, entitled "Pneumatic Transmission," has just been issued by the Republic Flow Meters Company. It contains a comprehensive and well-illustrated presentation of the principle of pneumatic force-balance and its use in industrial measuring instruments. The construction and operation of various types of pneumatic transmitters for the measurement of flow, pressure, level and density are fully described and illustrated.

Oil Burning System

Peabody Engineering Corporation has issued a new 4-page bulletin, No. 109, describing the Peabody CD (Constant Differential) Wide Range Oil Burning System. It explains how the system achieves efficient combustion over a range in capacity as great as 50 to 1, controlling any number of Peabody Burners throughout all variations in capacity. A copy of this bulletin will be sent free on request.

Refractories

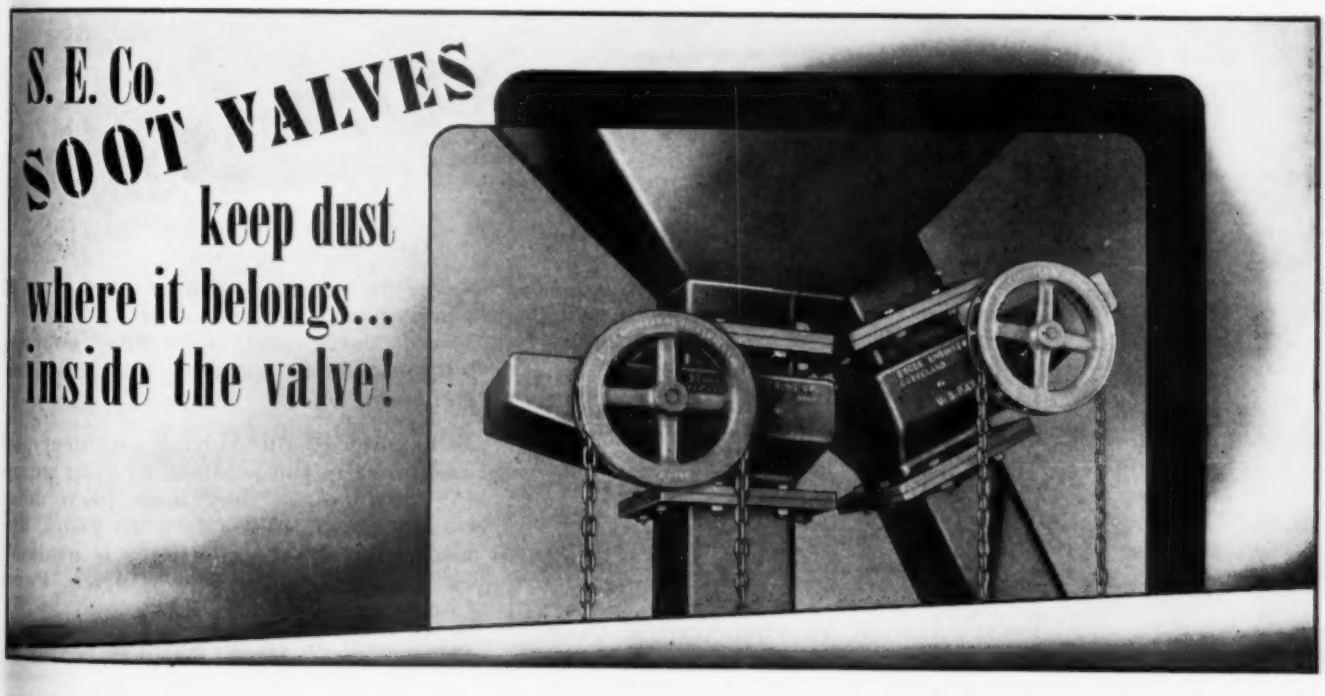
Chicago Fire Brick Company has issued a 4-page bulletin (No. 845) pertaining to its line of "Durabilt" Refractories for Industrial Furnaces. Illustrations show detail of standard wall and arch construction and the application of "Durabilt" products to four types of industrial furnaces.

Rotameters

Fischer & Porter Company has issued a bulletin (82-a, 83-A) describing its new Rotasleeve rotameter for measuring large flows of liquids and gases. Capacities and dimensions are given for Rotasleeves to fit standard pipe tees from 3 in. to 20 in.

Refractory Coating

Brickseal Refractory Company has issued a 4-page bulletin describing its product Brickseal Refractory Coating for the protection of brick or plastic refractories in oil-, gas-, or coal-fired furnaces. This product is available in four grades, for maximum temperatures ranging from 2000 to 3200 degrees F.



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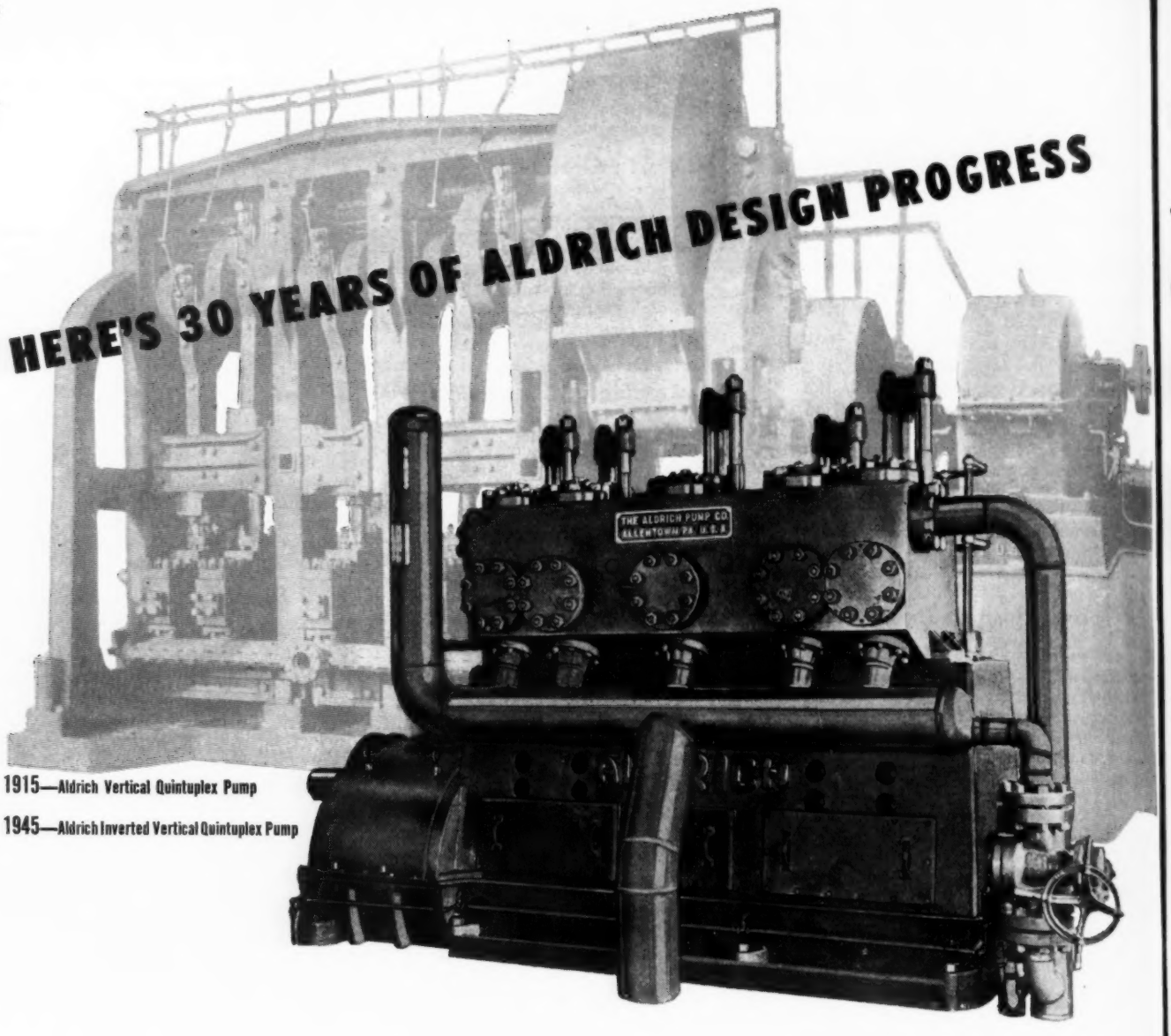

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VOLUME 17 **NUMBER 5**

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Editorial

High Pressure on Shipboard

It was just about twenty years ago that the first 1200-pound central station went into service. Since then this and very much higher pressures have become common among stationary plants, but the marine field was rather slow in following land practice. The first step was to advance to 400 pounds, then to 600 pounds for certain types of vessels, including many in the Navy. Of course, this does not apply to much of the war-time shipping construction which of necessity followed more conservative lines. It is also exclusive of certain more or less experimental installations involving higher pressures, both here and abroad.

Three years ago, it will be recalled, a high-pressure cargo ship operating with steam at 1200 pounds was put in regular service and within recent months this has been followed by the first of several ore carriers, the SS *Venore*, operating at 1400 pounds. A brief review of the propulsion machinery of this vessel is to be found elsewhere in this issue.

The principal object in adopting high steam pressure in this case was economy of operation in a service calling for long voyages and short time in port. By restricting the steam temperature to 740 F many of the complications of higher temperature were avoided and operation was simplified. Moreover, despite the high pressure, the machinery weights are comparable to those of a 425-pound vessel of similar tonnage and speed.

It would be presumptive to infer that this presages a general trend toward employment of such pressures in the marine field, but an analysis of the reasons given in this case points to the soundness of the decision to employ 1400 pounds for the particular conditions to be met.

Coal for Europe

In view of the present more or less unsatisfactory fuel situation in this country, there are some who, perhaps unthinkingly or without accurate knowledge, have been unsympathetic toward commitments already made for shipping limited quantities of coal abroad. However, the situation existing in various European countries, as reviewed by Mr. Potter in his talk before The Academy of Political Science, should make for a better general understanding of the dire needs of some of those countries.

It is basic that economic recovery is dependent upon fuel supply. With European sources dislocated by the war and German production complicated by splitting that country into four occupational zones the problem is intensified. The Ruhr, the largest of the coal-producing areas, is being operated by the British, and the next largest, the Saar, by the French. That occupied by the United States has very limited coal resources; and that occupied by the Russians is mostly brown coal.

It is significant that the loss in output in the United States during the current year by strikes would have supplied much of the coal that we are now committed to furnish Europe.

Efficiencies with River Anthracite on Traveling-Grate Stokers

By CHARLES S. GLADDEN

Chief Engineer, Heyden Chemical Corporation

The conversion of two water-cooled boiler furnaces originally designed for pulverized bituminous coal firing to the extended rear arch requirements for traveling-grate stokers is briefly described. Small sizes of river anthracite are used as fuel. Results of boiler tests, confirmed by regular operation, are discussed. An efficient method of cinder recirculation contributes toward maintenance of high overall efficiency.

IN SEPTEMBER 1943, The Heyden Chemical Corporation, as Architect-Engineer for the design of the Cherokee Ordnance Works, was directed to provide facilities for more than doubling the capacity of the plant at Danville, Pa. After preliminary negotiations, the Commanding Officer at Cherokee arranged with the Field Director of Ammunition Plants of the Ordnance Department for the transfer of two 110,000-lb per hr boilers which had become excess property at the Buckeye Ordnance Works at Ironton, Ohio. These boilers were designed for 475 psi operating pressure and for firing with pulverized bituminous coal. They were equipped with air preheaters, water-wall construction and both induced- and forced-draft fans.

After considering the advantages of burning small sizes of anthracite on traveling grate stokers as compared with the high maintenance charge to be anticipated in attempting to pulverize anthracite containing highly abrasive matter and the difficulties in burning this low volatile coal in pulverized form, it was decided that the pulverizing equipment could not be advantageously used, and that traveling-grate stokers would be better adapted to this purpose. The pulverizing equipment was therefore not transferred to Cherokee. The boilers had been erected and the hydrostatic test on both units had been completed when the cancellation order and directive to cease work on these units came to the Buckeye Ordnance Works.

The furnace-wall construction of these boilers was altered to adapt them to traveling-grate stokers with water-cooled extended rear arches. These alterations involved a complete redesign of the lower portion of the furnace; the same tubes were refabricated in many cases, and additional water-wall headers and downcomers were provided to insure proper water circulation. Provision was made in the installation of the boilers to have one unit arranged with steam-driven and one with motor-driven auxiliaries. Two C-E Lloyd-Coxe traveling-grate stokers were purchased and installed, one arranged with steam-engine drive and the other motor drive with a variable-speed control.

The complete dismantling of the boilers at Buckeye Ordnance Works, the conversion of the water-cooled furnace to conform to the requirements of traveling-grate stoker firing, and the erection of the boiler units, auxiliary equipment, air preheaters and new stokers was completed in June 1944 at which time both units were placed in operation.

The boilers, which were of the B & W Stirling type, were provided with cinder hoppers between the second and third passes, between the boiler outlet and the entrance to the air preheater, and at the bases of the stacks. The cinder hoppers were connected to the furnace, through the rear wall of the stoker setting, following the general practice for similar installations. The abrupt change of direction from downward to upward flow at both fly-ash hopper locations was considered to be effective in cinder precipitation. It was found after a brief period of operation, however, that the carbon loss due to fly ash to the atmosphere was of major magnitude, especially at the higher rates of combustion. A series of tests was conducted in the fall of 1944, with varying percentages of fineness in the coal and at different rates of combustion which established within reasonable accuracy the percentage of carbon loss to the atmosphere under different conditions when the cinders from the boiler hoppers were returned and recirculated in the boiler furnace. A series of tests was also conducted in which all of the fly ash entering the second and third passes of the boiler was collected and weighed, instead of being recirculated. The results from these tests have been used in estimating certain carbon losses as given in the results of boiler tests.

Boiler Tests

A series of overall boiler, furnace and air preheater efficiency tests was conducted to determine at what load the greatest economy in operation was obtained; what effect, if any, the higher percentage of fines in the coal had on the overall efficiency; and the carbon loss from the stack at various rates of steam generation. Preliminary efficiency tests were run in collaboration with a specialist from the Service Department of Combustion Engineering Company and final tests were conducted in June 1945 on the boiler that was equipped with steam-driven auxiliaries. The results obtained in previous special tests of the losses from fly ash passing through the stack to the atmosphere and from siftings of fine coal through the grate have been used in computing the corresponding

losses in the heat balance calculations for the boiler efficiency tests. Four tests were run for efficiency under varying conditions of load and with fuel having a wide range of fineness and moisture content. Essential data on the boiler, stoker, air heater, and other auxiliaries for this unit are as follows:

BOILER ALTERATIONS—The boiler tested was of the bent-tube, four-drum type having $3^1/_4$-in. tubes arranged 25 wide and 19 deep. It was originally designed for operation with pulverized, high-volatile, bituminous coal to generate 120,000 lb of steam per hour at 425 psi, the furnace having the conventional hopper bottom with front, rear and side walls completely water-cooled. The design of the furnace was changed when the boiler was transferred to conform to the requirements of a traveling-grate stoker with water-cooled rear and front arches, the tubes in the arches being protected with special enveloping refractory brick. Additional safety valve capacity, additional steam circulating tubes, and modification of the superheating surface were provided to adjust the boiler for suitable operation at 155 psi and 450 F total temperature which was necessary in order to operate at the same pressure and superheat as other boilers initially installed in the plant.

STOKER—The stoker having a grate surface 14 ft wide by 26 ft 6 in. long, was designed especially for burning small sizes of anthracite, with the forced draft controlled by nine zones, each with an individual adjustable sliding damper. Air is admitted to the zones from one side of the stoker. Provision is made for recovery of siftings through the grate by a steam-actuated suction nozzle which transports the siftings from a small screw conveyor in each zone and discharges them into the rear of the furnace. The stoker is driven by a 5-hp vertical steam engine.

FORCED-DRAFT FAN—This fan of the Sturtevant type, has a double inlet with radial inlet control dampers and is rated at 51,400 cfm. The wheel is 40.75 in. diameter and has backward curved blades. It is driven by a 75-hp geared Elliott steam turbine.

INDUCED-DRAFT FAN—This fan, manufactured by Green Fuel Economizer Co., is fully housed with double inlet boxes and of 72,100 cfm capacity. It has a 60-in. diameter wheel and radial discharge blades. Drive is by a 112-hp geared Elliott turbine.

AIR PREHEATER—The Ljungstrom air preheater is the revolving recuperative type with vertical axis and is driven by a 3-hp geared motor. A supplemental compressed air motor is also provided for emergency operation. The heating elements which were originally designed to heat the air for combustion to 450 F for burning pulverized coal were reduced in height so that the temperature of the air for combustion would be reduced to the limits allowable for a traveling-grate stoker.

TEST PROCEDURE—The methods used in procuring data and in preparing the test results were in general accordance with the A.S.M.E. Test Code for Stationary Steam Boilers—Short Form. Certain variations, however, were necessary because of local conditions. The methods used in such cases are outlined in the following paragraphs.

FUEL ANALYSIS—The ultimate analysis of the coal was made by the U. S. Bureau of Mines from a composite sample of samples taken during the tests at the delivery end of the Richardson weigh scale belt, and is representative of the general run of fuel available for this plant. The results of this ultimate analysis were as follows:

	Moisture-Free Per cent	Moisture-Ash-Free Per cent
Ash	17.2	
Sulphur	0.6	0.72
Carbon	75.4	91.06
Hydrogen	2.4	2.90
Nitrogen	0.9	1.09
Oxygen	3.5	4.23
	100.0	100.00
Btu per lb	12,150	14,670

ASH, BTU, MOISTURE—Moisture was determined by taking weighed samples of coal from the delivery end of the weigh scale at 15-min intervals. The weighed samples were placed in air-dried bags and were allowed to air dry for 48 hr in a layer about three inches thick over a floor grating where there was a continuous circulation of warm air. Finally, a riffled sample was sent to the plant's chemical laboratory where the moisture of the air-dried sample was determined, also the percentage of ash and Btu content. The final determination of moisture was found by combining the results of air drying with the chemical laboratory results.

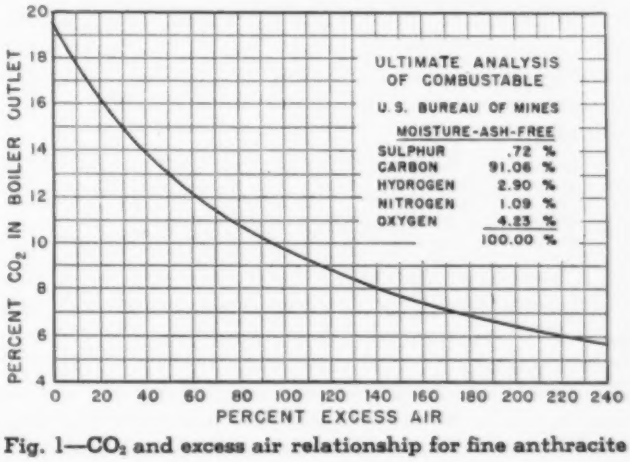

Fig. 1—CO_2 and excess air relationship for fine anthracite

SIZE OF COAL—The sample of coal for each test was also screened at the laboratory for percentages of fines by screening it for five minutes through $^3/_{16}$-in., $^3/_{64}$-in. and $^1/_{32}$-in., Nos. 50 and 80 standard screens in a motor-driven "Roto-tap" machine.

GAS ANALYSIS—The CO_2 content of the flue gas was determined by an Orsat operator who analyzed gas samples at 20-min intervals. It was also recorded by a "Micromax" instrument, which agreed reasonably well with the Orsat observations. The average of the Orsat readings, however, was used in the efficiency calculations. Search tests for carbon monoxide were made with the Orsat but no CO was found at any time.

Calculations were made of the air required for perfect combustion of one pound of dry ash-free combustible and of the total air required for various percentages of excess air. These results were plotted on a curve showing the CO_2 and excess air relationship for the particular coal of the ultimate analysis given above (see Fig. 1). Having the average CO_2 content of the boiler exit gases, the percentage of excess air was determined by reference to the CO_2 and excess air relationship curve. These values, together with a calculated factor of the ratio of

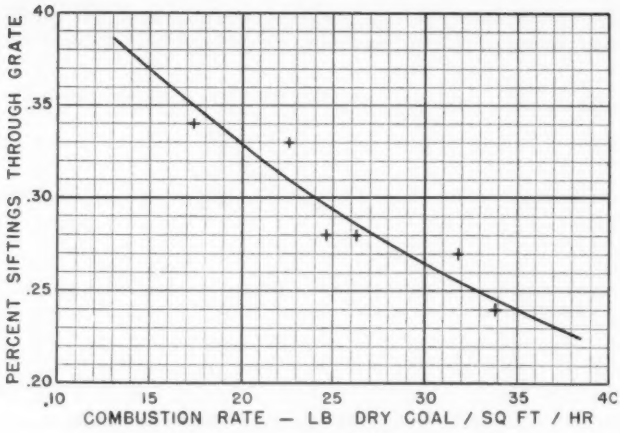

Fig. 2—Siftings through grate of stoker

weight of coal burned to weight of dry coal fired and percentage of combustible per pound of dry fuel, were then used to calculate the pounds of air required per pound of dry fuel in determining the dry gas at the boiler outlet and the air supplied per pound of dry fuel. Since the boiler is steel-encased, no allowance was made for air infiltration.

STEAM PRESSURE—The steam pressure at the superheater outlet was recorded by a calibrated recording test gage connected at the superheater outlet.

DRAFT—The drafts at various locations were shown by a Republic multi-point draft indicator which had been checked for zero readings previous to each test. Forced-draft pressures were shown on a similar forced-draft indicator.

TEMPERATURES—These were indicated at locations given in the detailed test reports by carefully calibrated mercurial thermometers permanently installed at each location. Temperatures by thermocouples were also recorded by a "Micromax" recorder which had been checked for accuracy. The temperatures of the gas and the air leaving the air preheater were taken on each side of the duct near the preheater and these were averaged in the test calculations. Correction for air leakage was made in determining the losses in dry chimney gases and in the heat-transfer calculations.

FUEL—The average ultimate analysis of the fuel, on a moisture-free basis, was sulphur 0.6 per cent, carbon 75 per cent, hydrogen 2.4 per cent, nitrogen 0.9 per cent and oxygen 3.5 per cent. The ash averaged about 17 per cent; the moisture, as fired, from 10.29 to 14.66 per cent; and the heating value per pound, as fired, 10,313 to 10,872 Btu.

The fuel as fired was weighed into the stoker hopper through a Richardson automatic coal scale which was checked and adjusted for balance before and during each test run. This scale weighs 200-lb charges, and an automatic counter registers the number of charges. Tests were started and stopped immediately after the hopper had been filled and the transverse screw conveyor had stopped. The scale continued to weigh coal into the feeder chute, and as soon as the chute was filled and the scale stopped, the automatic counter reading was taken. The time between the initial and final stopping of the transverse feeder screw was taken as the duration of the test.

REFUSE—The refuse was divided into three classes, namely, (1) ash-pit refuse, (2) fly-ash passing to the atmosphere, and (3) siftings through the grate. In normal operation the siftings are returned to the furnace through a steam-operated nozzle and are at least partially burned.

Ash-pit refuse samples were taken immediately after the test was completed. The ash bunker was arranged with three-hydrojet sluicing troughs. The two end portions of the ash bunker were first cleaned, which left the central section of ash refuse with an ash angle of repose at about 15 or 20 deg from the vertical. Samples were scraped vertically from both faces of the standing central ash pile and these samples were quartered and analyzed for unburned carbon.

Fly-ash loss to the atmosphere was determined by reference to the results of previous tests showing the total weight of fly ash passing through the stack to the atmosphere per hour at different rates of combustion. These data also include the per cent of carbon in the fly ash, and were obtained in a series of previous tests at different rates of combustion and with coal similar to that used during the efficiency tests.

The siftings through the grate were weighed after certain previous test runs for investigation of fly-ash production. An average "Siftings through Grate" curve (Fig. 2), falling within 0.02 per cent of actual readings between wide ranges of combustion rates, provides a basis for estimating siftings losses.

STEAM GENERATED—The actual steam generated was determined by a Bailey steam flow meter which had been carefully checked for accuracy. Correction factors for varying pressures and total temperatures were determined from a correction curve furnished by that company.

BLOWDOWN—The blowdown required to maintain concentration of solids between 1800 and 2200 ppm was determined by the difference between the feedwater flow meter and the steam-flow meter readings. The blowdown is passed through a flash tank in which about 13 per cent of the blowdown water is converted into steam at 12 psi, and the remaining water passes through a trap to waste. This small steam recovery has been neglected in these efficiency calculations.

AIR FOR COMBUSTION—This is supplied from the air preheater and by leakage and infiltration through openings in the stoker grate and the furnace brickwork, doors, etc. The air from the air preheater was taken as the amount required to absorb the heat transferred from the boiler gases, and the difference between the heated air and the total air required for combustion was assumed

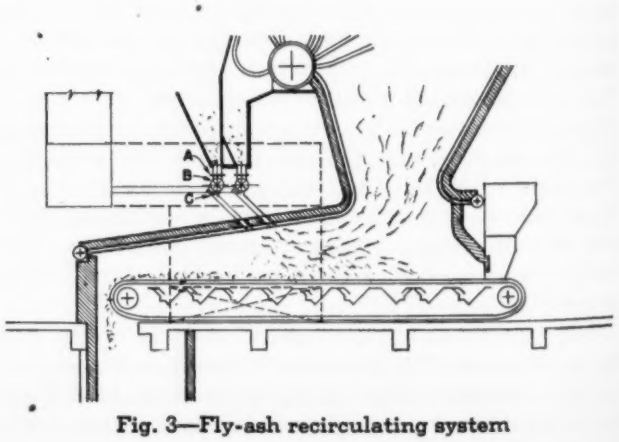

Fig. 3—Fly-ash recirculating system

to have been supplied through leakage into the furnace. Since the air at the operating floor is considerably cooler than that entering the air preheater, a weighted average temperature of the air for combustion was used in computing the heat loss due to dry chimney gases.

COMBUSTION CONTROL—The loads were maintained as nearly uniform as possible throughout the tests by a Hagan combustion control which automatically adjusted the speed of the stoker engine and the forced- and induced-draft fan turbines to maintain proper air flow-steam flow ratios and uniform furnace draft conditions.

Cinder and Fly-ash Recirculating System

The system of recirculating fly ash was developed after an experience with a pneumatic system of removing the fly ash with steam jets which induced currents of air through windswept valves at the base of each cinder hopper. The piping for this system failed by the abrasive action of the fly ash within 60 days of operation, and it required between one and two per cent of the total amount of steam produced by the boiler to operate the steam jets. The revised arrangement consists of revolving cinder traps placed at the outlet of each cinder and fly-ash hopper which discharge directly into pipes leading downward through the roof of the furnace at an inclination of 45 deg toward the front. These feeder pipes are supplied with hot air from the forced-draft system by a pipe connected to the duct between the air preheater and the stoker windbox.

The arrangement is indicated in Fig. 3.

A sliding gate is installed at the bottom of the cinder hopper at point *A*. The revolving cinder trap at location *B* is operated by a $^1/_6$-hp geared motor at 24 rpm. This revolving trap prevents gases from passing upward from the furnace into the outlet of the cinder hopper. There is approximately 0.65 in. to 1.0 in. differential pressure between the furnace and the fly-ash hopper. This would normally cause an upward draft which would tend to prevent the flow of cinders downward. This upward draft, however, is effectually cut off by the action of the revolving cinder trap at point *B*. The vanes of the cinder trap have a $^1/_{16}$-in. clearance between the cylindrical walls and the ends of the trap but leakage through these clearance spaces is so slight that it does not affect the flow of cinders downward through the trap. At location *C* a blast of hot air from the forced-draft system is injected into the delivery pipe, and gives additional impetus to project the cinders into the furnace and also surrounds the cinders with heated air which promotes combustion. In observing the furnace interior, one can readily see the burning of the finer cinders in suspension as soon as they enter the furnace. Thus the cinders recirculate through the furnace and boiler passes until they are finally consumed. The amount of carbon in the ash was investigated by spot checks across the rear end of the stoker. The cinder delivery spouts did not appear to create zones on the grate where the amount of carbon in the ash was greater than at other locations across the grate.

Test Results

The curves, Fig. 4, show the combined boiler, stoker and air preheater efficiencies at different steaming rates; temperatures of the gases leaving the boiler and after passing through the air preheater; dry gas loss and combustible in both the ash pit and in the fly ash. There is

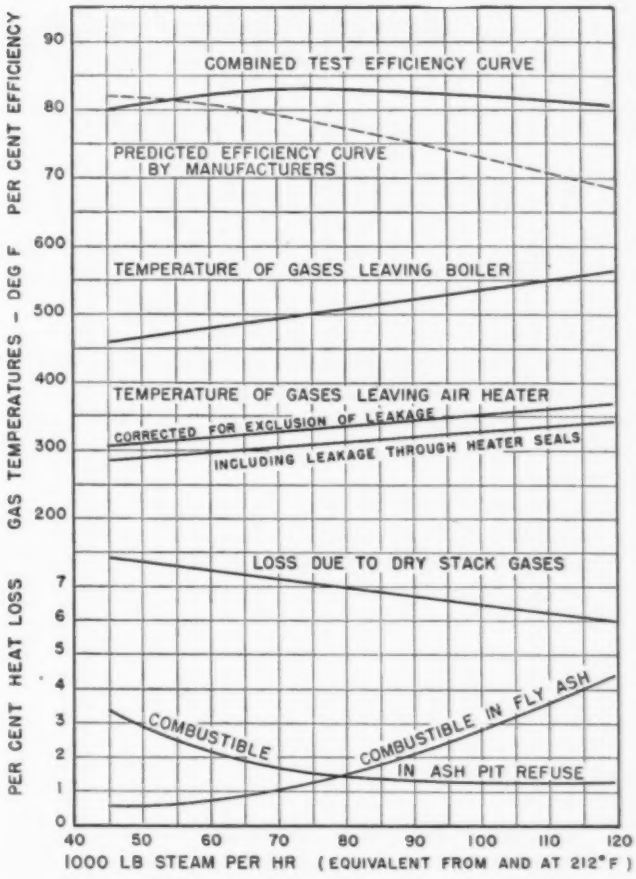
COMBINED TEST EFFICIENCY CURVE
PREDICTED EFFICIENCY CURVE BY MANUFACTURERS
TEMPERATURE OF GASES LEAVING BOILER
TEMPERATURE OF GASES LEAVING AIR HEATER
CORRECTED FOR EXCLUSION OF LEAKAGE
INCLUDING LEAKAGE THROUGH HEATER SEALS
LOSS DUE TO DRY STACK GASES
COMBUSTIBLE
COMBUSTIBLE IN FLY ASH
IN ASH PIT REFUSE
GAS TEMPERATURES - DEG F
PER CENT EFFICIENCY
PER CENT HEAT LOSS
1000 LB STEAM PER HR (EQUIVALENT FROM AND AT 212°F)

Fig. 4—Test results at different steam outputs

a certain amount of air leakage from the forced-draft inlet side of the heater through its seals to the exit gases in the gas outlet side. The amount of this leakage is assumed to be in accordance with a leakage curve provided by the air preheater manufacturer. The exit gas temperatures have been corrected for the cooling effect of the air leakage, and the results are shown by the curve marked "Corrected for Exclusion of Leakage."

The predicted efficiency curve is drawn through the estimated efficiencies at half, three-quarters and full load steaming rates as submitted by the equipment manufacturers. The reason for the higher efficiencies obtained by tests at the higher ratings over that predicted is due primarily to the effective burning of the cinders in the fly ash by the method of recirculation developed at Cherokee. At a load of 100,000 lb per hr, the loss due to unburned combustible is 4.2 per cent, while the predicted unburned combustible loss was 14 per cent.

A summary of the heat balance, in per cent, at four outputs is as follows:

	—Output in Pounds per Hour—			
	54,160	73,548	97,433	119,720
Heat absorbed by water and steam in boiler and superheater, per cent	81.9	83.1	82.2	80.8
Loss due to moisture in coal, per cent	1.	1.3	1.3	1.4
Loss due to combustion of hydrogen, per cent	2.1	2.2	2.2	2.2
Loss due to continuous blowdown, per cent	1.	0.6	1.4	1.4
Loss due to dry chimney gases, per cent	7.7	7.2	6.4	6.0
Loss due to combustible in ash refuse, per cent	2.6	1.6	1.3	1.4
Loss due to combustible in fly ash, per cent	0.6	1.2	2.6	4.4
Loss due to siftings through grate, per cent	0.4	0.3	0.3	0.3
Radiation and unaccounted for, per cent	2.7	2.5	2.3	2.1

At Cherokee Ordnance Works the boiler, furnace and firing equipment has proved very successful in utilizing the fine river anthracite fuel. In regular service the two 110,000-lb per hr units have operated at a monthly average combined efficiency of over 82 per cent.

EUROPE'S COAL PROBLEM*

By C. J. POTTER

Deputy Solid Fuels Administrator

THE United States is the world's leading coal producer, followed by Germany, the United Kingdom, the newly expanded Poland and Russia.

When the Allied Air Force paralyzed the German war machine her ability to produce coal was also paralyzed. Physical destruction, coupled with the desire of the Allies not to permit German industry to return to its pre-war status, creates a void in European economy, of which coal is the heart.

At the beginning of the war, the United Kingdom exported almost 50,000,000 long tons of coal, about 70 per cent going to continental nations. After the fall of France and disappearance of the continental market, the British continued to stockpile coal. With invasion imminent, imperative demands for manpower in the armed forces and in munition industries shifted thousands of miners from the collieries. War requirements for fuel began to rise, and no replacements for normal labor attrition were available. Too late the Government began to draft men into the mines, but efficiency declined perceptibly. Loss of experienced miners could not be offset by mechanization or changes in operating methods. Stiff taxes and the prospect of nationalization proved discouraging to owners. Production continued to decline and it was still declining in August of this year. Today, with exports at a low level, the United Kingdom is itself deficient in coal supplies. British domestic ration of coal is 2.3 tons per year in the South and 3.3 tons in the North, irrespective of family size or the house.

When France was overrun she had been producing about three-fifths of her normal peacetime requirements of coal. The Germans immediately diagnosed the problem and, while forcing French mines to maximum production, began to move German coal into France to offset the loss of British coal. Slave labor was forced into French mines to offset drop in productive efficiency.

Before the invasion of France by the Allies, General Eisenhower established a Solid Fuels Section. Army Engineers went into the French mines before all of the Germans were out and started operation while still under enemy shell fire. They were faced with no mine supplies, disrupted and destroyed transportation, and a terrific labor shortage brought about by the freeing of slave labor, together with dispersal of French miners in search of food and clothing. Despite these handicaps, by the time our army crossed the Rhine, French coal output was approaching 40 per cent of pre-war production. The French then took over operation and have increased production to 85 per cent of pre-war tonnage.

One of the least damaged of the countries was Belgium which will return to normal standards of living before France and The Netherlands. Foreseeing a situation in Belgium similar to that in France, S.H.A.E.F. placed United States mining men there immediately upon liberation and they solved to a great extent the same problems encountered in France. The Belgium Government gave coal mining number one priority, and as soon as part of Germany was conquered, began to recruit liberated displaced persons for its mines, as well as assigning German prisoners to such work. The Belgium coal operators began to train, feed, and clothe these men with the result that coal production is now 55 per cent of normal. Despite her shortage, Belgium is exchanging coal with countries, such as Switzerland, for critically needed mine supplies. She is also buying low-grade anthracite from the United States.

Netherlands Suffered Most

Hardest hit were the Dutch who were practically self-sufficient in coal before the war. They willingly, upon radio advice from London, sabotaged mines, transportation, utilities, and the food-processing industries with the understanding that upon liberation, the Allies would take care of them, but until a short time ago, there was little coal available to public utilities for manufacture of gas and electricity. There was no coal to run industries and no dissemination of news because newspapers could not be printed and radio stations were useless without electricity. Moreover, the Dutch had no fuel with which to cook their food except by chopping down what few trees remained and further tearing up paving blocks. It has been impossible to pump inundated areas, hence production in agricultural areas is still a long way off. Coal production in The Netherlands is still only 40 per cent of normal and about 100,000 tons a month of U. S. coal is being purchased, in addition to some from Germany.

Denmark's source of coal before and during the war was from England and Germany. Since the destruction of transportation facilities and collapse of German mining, Denmark has had no source of fuel supply. Although during German occupation her economy was at or above pre-war level, she is now entering a terrific slump. Only fuel for cooking, transportation and what can be obtained for food processing is now being allocated. This will mean a decline in production of foodstuffs which Europe needs so badly.

Pre-war Norway relied entirely upon imports of coal, chiefly from the United Kingdom, and was supplied by Germany during the war. She is now receiving approximately 50 per cent of her minimum requirements, and through the use of wood and hydroelectric power will be able to stage an economic recovery.

Before the war, Italy imported 12,000,000 tons yearly, of which 7,000,000 tons came from Germany. This was used mostly in the northern industrial areas. Railroads and industries of central and southern Italy primarily used hydroelectric power, which was destroyed by both the Germans and Allied armies. This forced the Allies to use coal-burning locomotives as well as to use coal as a source of energy for the industries that were permitted to operate to aid the Allied armies. Destruction in the north of Italy was limited and Italian industries would be

(*Continued on page 45*)

* Excerpts from a talk before The Academy of Political Science, November 8, 1945.

Improvements in Thermal Efficiencies with High Steam Pressures and Temperatures*

Reference is made to a paper prepared by the author and H. C. Lamb in 1938[1]; also to two papers by Dr. H. L. Guy[2] in which values from earlier steam tables were used. However, more recent calculations based on the 1939 steam-table values show that the improvements possible with higher pressures and temperatures are appreciably lower than those estimated on the basis of the earlier tables at pressures above 1000 psi. The differences are plotted and curves given for improvements under various conditions, using the present steam-table values and a non-reheating steam cycle.

By K. BAUMANN

Chief Mechanical Engineer
Metropolitan-Vickers Electrical Co., Ltd.

DIFFERENCES in the improvements of thermal efficiency with higher pressures and temperatures are plotted in Fig. 1, the full lines representing improvements according to latest steam-table values and the broken lines those given in the earlier paper. The determinations of thermal efficiencies obtainable with a non-reheating cycle using regenerative feedwater heating are carried out for pressures of 600, 900, 1200 and 1800 psi with steam temperatures of 800, 850, 900 and 950 F. The following eight conditions were assumed:

1. A constant dry-stage turbine efficiency of 85 per cent in a turbine designed for 600 psi.

2. A decrease in turbine-stage efficiency for turbines designed for the higher pressures at the rate of 1 per cent for a pressure ratio of 2.

3. A decrease in turbine-stage efficiency in the wet region of 1 per cent for each 1 per cent mean wetness per stage. A reduction in the wetness correction of 25 per cent (i.e., 0.75 per cent for each 1 per cent) would decrease the rate of improvement in thermal efficiency with higher temperature by 5 per cent and increase the improvement with higher pressure by a similar amount within practical ranges of steam conditions. A change in the wetness correction does not appreciably affect the predicted improvement with higher steam conditions.

4. A vacuum at the turbine exhaust of 29 in. Hg. For a lower vacuum the improvement with higher pressures would be increased.

5. A constant leaving and exhaust loss expressed as a loss of heat drop in Btu per lb.

6. Five stages of feedwater heating in line with modern practice. The effect of a greater number of feed-heating stages does not appreciably affect improvements. For instance, the improvement due to seven stages of feedwater heating, as compared with five, is about 0.2 per cent with 600 psi and 0.5 per cent with 1800 psi. The feed temperature chosen is that which gives a thermal gain due to feed heating 0.27 per cent less than the maximum possible gain.

7. The powers required by both turbine-room and boiler-house auxiliaries have been calculated individually

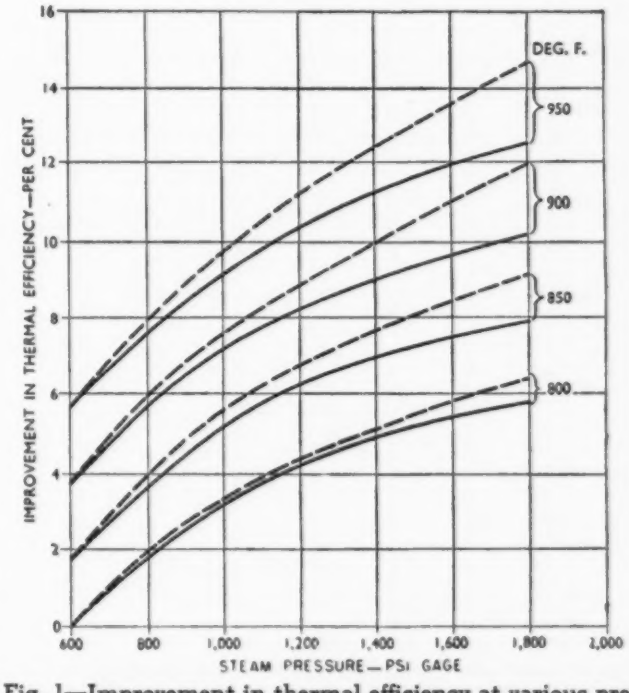

Fig. 1—Improvement in thermal efficiency at various pressures and temperatures, related to 600 psi and 800 F. Solid lines based on present steam-table values, whereas broken lines represent old values

* Excerpts from a paper presented before The Institution of Mechanical Engineers (British) July 31, 1945.

[1] "Present-Day Trends in Power Station Practice," *Proceedings* of the Incorporated Municipal Electrical Association, 1938.

[2] "Economic Value of Increased Steam Pressure," *Proceedings* of the Institution of Mechanical Engineers, 1927; and "Tendencies in Steam Turbine Development," *Proceedings* of the Institution of Mechanical Engineers, 1929.

on the basis of present-day practice, and in particular centrifugal boiler-feed pumps have been assumed throughout. The increase in power required by the auxiliaries on raising the pressure from 600 to 1800 psi is 2 per cent of the output of the turbine with a steam temperature of 800 F, and 1.7 per cent with a steam temperature of 950 F. This increase represents the difference between the increased power required by the boiler-feed pumps and the savings in power of all other auxiliaries with increased pressure. Allowance has also been made for the gain due to the rise in temperature of the feedwater in the boiler-feed pump.

8. It is assumed that the efficiency of the boiler plant, excluding the power required by the auxiliaries but including steam pipe losses, remains constant; and that is not affected by the higher feed temperatures required for higher pressures.

Recommended Amendment to Basis of Calculations

In line with the earlier calculations mentioned, no allowance was made for an increase of gland and other losses with increased temperatures, so that the estimated improvements with higher temperatures may be regarded as slightly optimistic. Therefore, it would be reasonable to suggest a reduction in the rates of improvement with higher temperatures varying from 5 per cent at a pressure of 600 psi to 15 per cent at 1800 psi, to allow for the effect of increased clearances. With such a correction the improvement in thermal efficiency with higher temperatures becomes 0.35 per cent for every 10 deg F increase in temperature and is independent of the pressure.

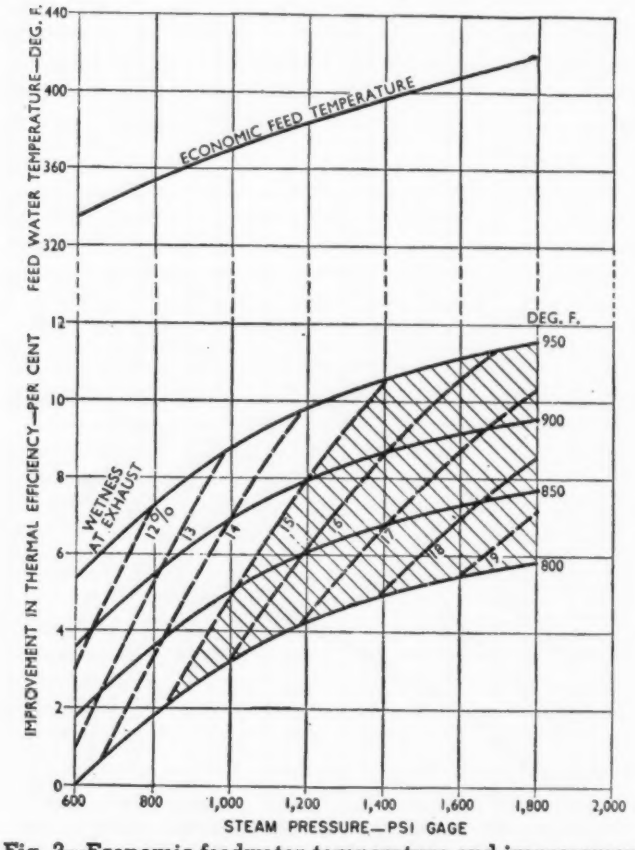

Fig. 2—Economic feedwater temperature and improvement in thermal efficiency with pressure

The curves corresponding to recent calculations, as shown in Fig. 1, corrected for this additional allowance, are given in Fig. 2, which also shows the curves of constant wetness at the turbine exhaust and the feed temperatures assumed for the calculations. As the wetness is limited by well-known considerations, the shaded parts of the curves have no practical significance at present.

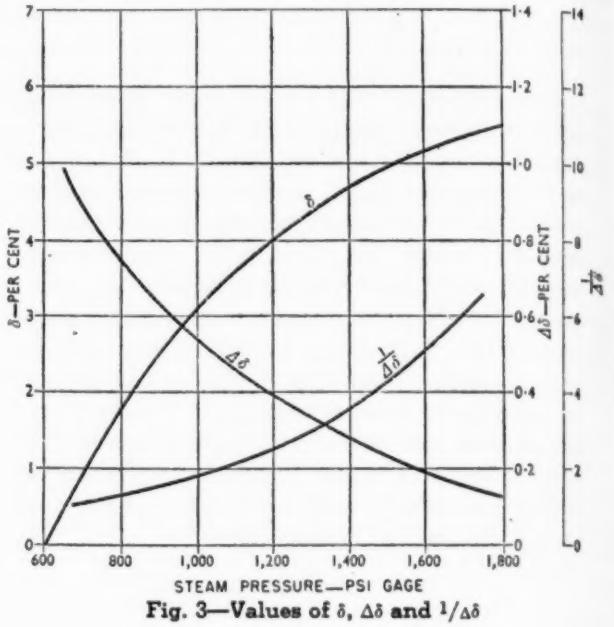

Fig. 3—Values of δ, $\Delta\delta$ and $1/\Delta\delta$

It is to be understood, of course, that these apply only to large plants of at least 50,000 kw and that for smaller units the improvements would be less.

Economic Pressure

In the discussion of the earlier paper mentioned, also in a lecture delivered before the Institution of Engineers, Australia, in 1938, the author dealt with the determination of the economic pressure based on improvements in thermal efficiency with higher pressures. It was shown that the economic pressure depends upon the following five factors.

1. Cost of fuel.
2. Calorific value of the fuel.
3. Plant load factor.
4. Rate of capital charges which also may include a rate for maintenance.
5. Increase in capital cost of plant per kilowatt capacity for an increase in pressure of 100 psi gage.

The first four of these items represent operating conditions, and their collective effect on the capital value of any fuel saving depends on an operation factor m which is defined as:

$$m = \frac{\text{Cost of fuel per ton}}{\text{Calorific value in Btu per lb} \div 10{,}000} \times \frac{\text{Load factor referred to installed capacity}}{\text{Rate of capital charges, per cent}}$$

The capital value of the saving in heat consumption

per kilowatt capacity by raising the pressure above 600 psi is given as

$$\Delta C = \frac{m\delta}{0.75\eta_{th}}$$

where δ is the percentage reduction in heat consumption by raising the pressure above 600 psi and η_{th} the percentage thermal efficiency of the power station operating at 600 psi.

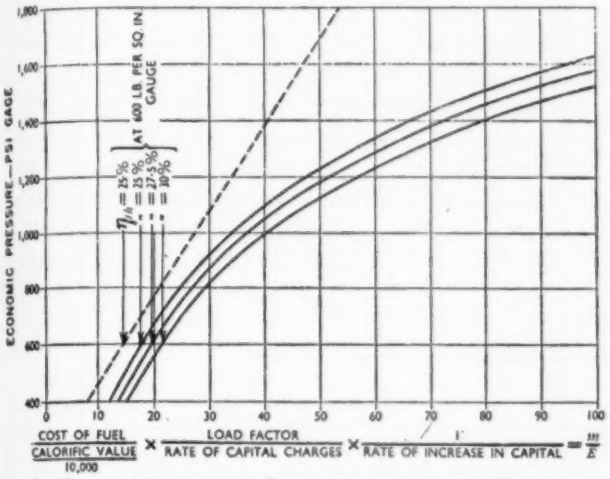

Fig. 4—Economic pressure for various operating factors and rates of increase in capital cost per kilowatt installed.

The percentage reduction in heat consumption δ is obtained from the percentage improvement in thermal efficiency ϵ as

$$1 - \frac{\delta}{100} = \frac{1}{1 + \frac{\epsilon}{100}}, \text{ or } \delta = \frac{\epsilon}{1 + \frac{\epsilon}{100}}$$

According to the recommendations previously made herein, the improvement in ϵ, with increase of pressure is independent of temperature; and it follows therefore that δ is also independent of temperature. The values δ, also $\Delta\delta$, where the latter is the change of δ for every 100 psi increase in pressure, are plotted in Fig. 3 as a function of the mean pressure of the 100-psi pressure ranges.

The economic pressure condition requires that the capital value of the saving in heat consumption, by raising the pressure 100 psi gage, shall equal the additional capital outlay E involved. Therefore:

$$E = \frac{m\,\Delta\delta}{0.75\eta_{th}} \text{ and } \frac{m}{E} = 0.75\eta_{th}\,\frac{1}{\Delta\delta}$$

The curve for $\frac{1}{\Delta\delta}$ in Fig. 3 therefore represents the ratio m/E to an approximate scale, depending on the expected thermal efficiency.

This curve is replotted in Fig. 4, showing the economic pressure as a function of m/E for efficiencies at 600 psi and 25, 27.5 and 30 per cent. The broken line represents the economic pressure obtained for the earlier calculations based on a thermal efficiency of 25 per cent. These curves apply to plants operating at an average vacuum of 29 in. Hg. For plants operating at 28 in., the improvement in heat consumption with higher pressure is 17.5 per cent greater, and the economic pressure can be obtained from the curves in Fig. 4 by substituting $1.175m/E$ for m/E. Making allowance for the fact that the basic efficiency at 600 psi will be about 5 per cent lower for 28 in. than for 29 in., it will be found that the economic pressure for 28-in. vacuum is about 125 psi higher than that for 29 in.

There may be difficulties in applying the results from Fig. 4 in actual practice, since determination of load factor over the life of the plant involves considerable speculation; and also determination of the increase in capital costs with increased pressure is not a simple matter, if all factors and secondary effects are to be taken into consideration.

Fuel Handling and Oil Atomizing Features of a Small Industrial Boiler Plant

By PERRY HAYNES

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Lifting of wartime restrictions on the use of fuel oil has resulted in some steam plants, that formerly burned oil but were temporarily denied its use during the emergency, reconverting to the fuel for which they were originally designed.

One such small plant is that of the Holliston Mills, Inc., processors of specialty fabrics, in Norwood, Mass. It is located in the Metropolitan Boston area where waterborne transportation and short local haul makes it possible to deliver the oil at an attractive price. A description of the fuel-handling system and certain features of the combustion equipment is of interest.

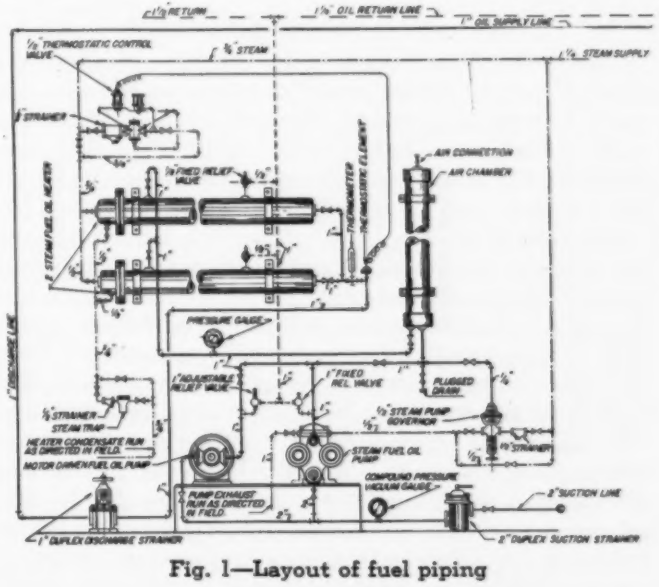

Fig. 1—Layout of fuel piping

Steam is supplied by a 27,000-lb per hr C-E type VM3, low-head, three-drum, bent-tube boiler designed for 450 psi and 100 deg superheat. It was originally

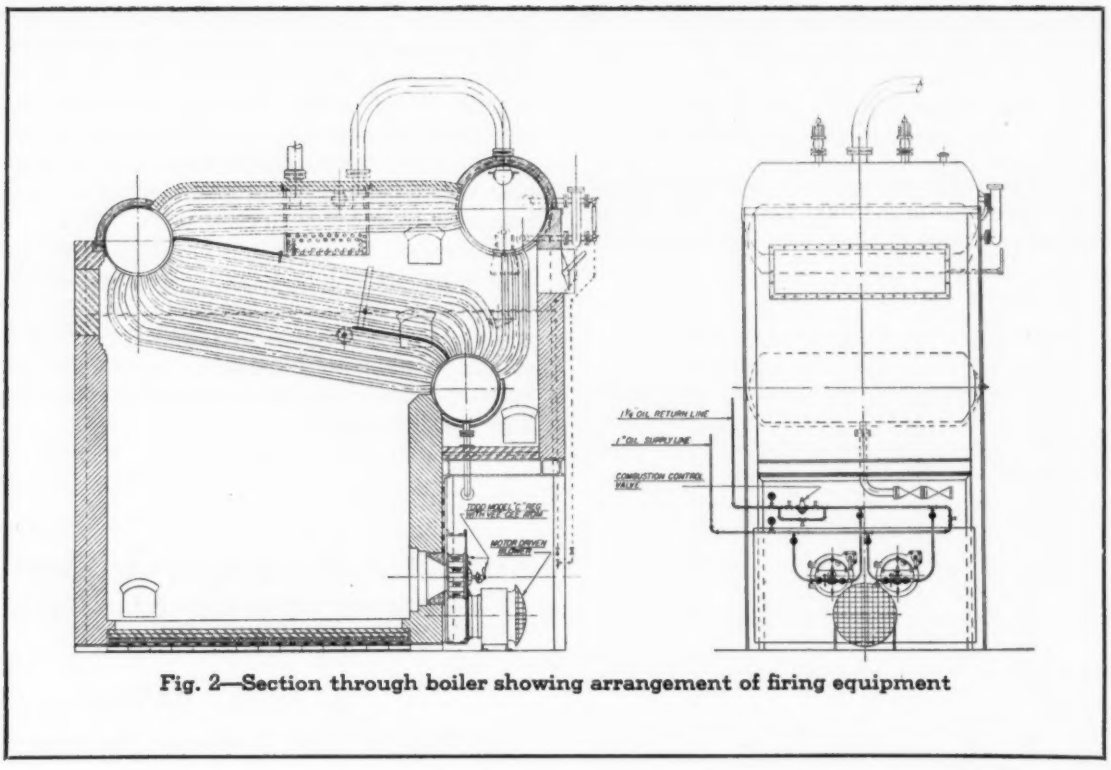

Fig. 2—Section through boiler showing arrangement of firing equipment

equipped with steam-atomizing burners, but in the reconversion mechanical atomization was decided upon, for which purpose Todd "Vee-Cee" variable-capacity return-flow atomizers were selected in order to meet the particular load conditions and take full advantage of automatic combustion control over the wide load range required for the plant's operation. The steam generated is used for operating a turbine-generator, the exhaust from which is employed for process and heating. Demands cover the usual wide span common to such installations.

Fuel Supply and Handling System

The fuel storage consists of two 15,000-gal cylindrical storage tanks. These are buried underground and located so that oil can be delivered by gravity from a railroad tank car or from a motor truck. The tanks are fitted with a steam heating coil for preheating the oil prior to pumping.

The fuel supply system is in duplicate and consists of two pumps—one a steam-driven horizontal duplex type and one a motor-driven rotary, each capable of delivering the fuel to the atomizers at 300 psi. The delivery pressure is maintained by conventional regulating valves. A duplex strainer is fitted in the suction line and a similar high-pressure strainer is installed in the discharge line. The baskets in either strainer can be cleaned without interrupting operation. A pair of tubular oil heaters are installed to provide proper final temperature for the oil prior to atomization, and steam supply to these heaters is controlled by thermostatically actuated valves. An air chamber to dampen pressure fluctuations, when operating with the piston pump, is also placed in the supply system. All piping and valves on this system are designed for 300 psi operating pressure. A diagram of the fuel supply piping is shown in Fig. 1.

The combustion equipment on the boiler is shown in Fig. 2. It consists of two Todd "Model C-16" air registers, equipped with standard "Vee-Cee" atomizers, which operate on the return-flow principle, in which control of the quantity of oil returned to the source of supply regulates the quantity atomized. Use of this type of atomizer permits the plant to operate automatically over its full load range without requiring the usual changing of atomizer tip sizes. The registers are installed in a plenum chamber and are designed with the atomizer assembly carried in a hinged swinging door which provides ready access for adjustment and replacement of parts. Access to the boiler furnace is also available through the register door opening, thus eliminating the necessity of a complete or partial register removal or the removal of a bricked-up refractory opening in the furnace side wall.

Air for combustion is furnished at low pressure by a motor-driven constant-speed fan, the quantity delivered being controlled by adjustable louvers located on the fan inlet.

The fuel supply to the atomizers and air furnished by the blower are automatically controlled by a hydraulically operated system through a master regulator actuated by the steam pressure. The oil and air ratio is maintained over the full range of load by a regulator which responds to draft differential and oil flow. Furnace draft is maintained constant by an overfire draft regulator which actuates a damper on the boiler outlet. The furnace is of conventional design with suspended lining and an air-cooled floor, and the boiler is equipped with the usual instruments for a plant of this type and size, including a recording steam flow meter, CO_2 recorder and stack pyrometer.

Installation work was done by the Perfection Grate & Stoker Company of Springfield and Boston, Mass.

Conference Stresses Feedwater and Boiler Water Problems

Among the topics discussed at the Sixth Water Conference were the behavior of highly concentrated boiler water, cold water vacuum deaeration, boiler scale studies at 1500 psi, ion exchange water conditioning, electrolytic softening and feedwater practice in Germany. Abstracts of the papers on these subjects are here given, but space does not permit inclusion of the extensive discussion which will be available when the Proceedings of the conference are published.

THE Sixth Annual Water Conference, sponsored by the Engineer's Society of Western Pennsylvania, was held at the William Penn Hotel in Pittsburgh, Pa., on October 22–23, with a registration of over 325. A number of papers in the steam generating field were presented.

High Boiler Water Concentrations

In a paper entitled "The Behavior of Highly Concentrated Boiler Water," Messrs. Kaufman, Marcy and Trautman of the Hall Laboratories outlined the theory of the concentrating boiler water film at the steam generating surfaces, and presented experimental data on the solubility and corrosiveness of boiler water salts.

Boiler water, at concentrations shown by the usual analysis, can be considered dilute and non-corrosive, but hideout, scale formation and/or corrosion may occur when such waters concentrate. Hideout occurs when boiler water salts of relatively low solubility become concentrated in a boiling film of boiler water at a point of high heat transfer, and begin to come out of solution on the tube surface. Such precipitation of salts may not, in itself, be serious, but is an indication of a condition that may cause trouble. The sodium sulphate and phosphate in the boiler water are the usual hideout offenders, sodium chloride and hydroxide being much more soluble. In contrast to the sodium salts, those of potassium are much more soluble and hideout can be eliminated by substituting potassium salts for sodium salts in the boiler water treatment.

Corrosion within the boiler tubes may occur when the normal alkalinity of a boiler water concentrates sufficiently to destroy the protective oxide coating on the metal. The effect of a dilute boiler water, of normal composition, is to form and maintain a thin protective coating of iron oxide on the tube surface. As a boiler water concentrates, however, particularly as its alkaline constituents concentrate, a point is reached where the protective coating is dissolved and the tube metal becomes exposed to oxidation by the bonded oxygen of the water. The metal reduces the water, combining with its oxygen and liberating its hydrogen.

Concentration of a normal boiler water, sufficient to cause corrosion and hideout, is explained by the theory of the concentrating boiler water film. The water and steam in a boiler are normally at the temperature given in steam tables for the pressure involved. Locally, however, at points of poor circulation or of high heat transfer, the temperature of the water and steam may be considerably higher than that corresponding to the pressure.

Phase Rule Applied

By application of the Phase Rule, it follows that, in a constant pressure system, a local increase in temperature results in a counterbalancing increase in concentration. The extent of concentration is a function of the temperature difference set up at the hot spot, the materials present in the boiler water, their relative amounts with respect to each other, and of their limiting solubilities.

Local hot spots in a boiler circuit are possible in the upper portion of inclined boiler tubes where there is partial separation of steam from the circulating mixture, and in vertical tubes where high rates of heat transfer set up film boiling and steam blanketing. Concentration of alkaline salts in such areas often results in internal corrosion, grooving and tube failure.

Laboratory determinations of the solubility of boiler water constituents were made by determination of the vapor pressure variation, with temperature, for saturated solutions. There is a direct relationship between solubility, vapor pressure and the temperature difference between the concentrated solution and the temperature given in steam tables for the pressure involved. These data were determined for both solo solutions and mixtures of both the sodium and potassium salts. Pertinent to the corrosion problem was a curve prepared by the authors, showing concentrations of ten to twenty per cent caustic concentration attainable in boiling films under local superheat conditions of 15 to 30 deg F.

In concentrating systems, the demand for concentration is shared by all salts in solution. The presence of very soluble salts, such as sodium chloride and salts of the potassium family, greatly reduces the concentration of hydroxides at the hot spot and may prevent corrosion. When the hydroxide is associated with relatively insoluble salts that hide out easily, the burden of concentration falls on the caustic and relatively high concentrations can develop which cause corrosion and failure.

Additional experimental data on the corrosiveness of boiler water salts were obtained by establishing equilibrium conditions in a test bomb under various conditions and determining the residual pressure set up in the bomb after cooling, by the hydrogen liberated in the bomb by corrosion. The results are consistent with the theory

involved and there is little doubt but that the theory of the concentrating boiler water film will become a valuable tool in the analysis of boiler corrosion problems.

German Water Conditioning Practice

An interesting, but unscheduled, talk on "German Power Plant Water Conditioning Systems" was given by W. W. Cerna of the Hall Laboratories who was one of a group of six technical experts sent to Germany early in May by the Government to report on power plant developments and practice. Many plants were inspected and operators, chemists and consultants interviewed.

Basically, the various methods of water conditioning in Germany are similar to those used in this country. In general, German waters are hard, and in many cases are contaminated with industrial wastes. Chemical treatment is necessary and is used on a large scale.

Silica content of boiler waters in Germany is generally limited to less than 7 ppm for high-pressure operation, and silica removal systems are an important part of the water conditioning. For cold-process silica removal, a combination of magnesium chloride and sodium aluminate is used as the active reagents. Residual silica content of 1 ppm in the treated water is the usual goal. Hot-process systems for silica reduction are similar to American practice. Dolomitic lime, lime and magnesium oxide, or caustic soda and magnesium oxide are used to give a combination of carbonate hardness and silica reduction.

For high-pressure boilers, condensate feedwater systems are the usual standard, even though process steam requirements are high. Where treated makeup water is used, final softening by either hot phosphate units or base-exchange softeners is always employed. Internal phosphate treatment is universally used in German power stations.

Incidently, Mr. Cerna mentioned that at Mannheim, which was badly damaged by both air raids and artillery action, the large central station had received only minor damage. Early in the war an underground extension had been built which contained a 35,000-kw turbine-generator. Peculiarly, this underground extension suffered more bomb damage than that above ground, due to the shock transmitted to the 35,000-kw unit, through a thick concrete roof when a bomb exploded above it. The unit was put out of service for two weeks.

Vacuum Deaeration

A paper on "Cold Water Vacuum Deaeration," by Sheppard T. Powell, consulting chemical engineer, described recent developments in the degasification of large volumes of cold water by vacuum deaeration. The process is based on the fact that if a liquid is distributed in a thin film and a vacuum applied, the dissolved gases such as oxygen and carbon dioxide, will be reduced to a relatively small residual amount. Further deaeration can be obtained by multiple-stage units or secondary chemical treatment, if economically feasible.

Mr. Powell described two large-scale deaeration systems, one in Australia and one installed by the Freeport Sulfur Co. at Port Sulfur, La. At the latter plant, the deaerator was designed to deaerate about four million gallons of water per day, which was pumped through some ten miles of steel pipe line. Originally installed in 1935, without deaeration, the capacity of the line decreased 22 per cent in 129 days because of active corrosion and tuberculation in the line. Installation of a vacuum deaerator, supplemented by additional sodium sulphite treatment, corrected the corrosion and the system has been in continuous and successful operation for nearly ten years.

The purchase cost of single-stage installations can be estimated at $10,000 for a thousand gallons per minute of water treated, plus $3000 for each additional increment of 1000 gallons per minute. Operating costs depend on availability of steam or power and the completeness of deaeration desired.

Deaeration performance for a number of smaller installations described by the author, showed reduction of oxygen to values ranging from 0.2 to 0.6 milliliter per liter. Vacuum pressures vary from 25 to 28 in. of mercury, depending on the design and operation, which in turn is governed by the initial cost and operating charges.

Boiler Scale Studies

J. A. Holmes, of National Aluminate Corporation, presented an interesting paper on "Experimental Studies of Boiler Scale at 1500 Psi," which was a continuation of previous studies made under similar conditions at 800 psi. The presentation was largely pictorial with slides showing magnified deposits on a heating element under various boiler water conditions. The results of the tests indicated that magnesium in the presence of phosphate under some conditions, causes deposits. Greater amounts of organic colloid are required to condition sludge as the boiler pressure and the magnesium content of the water increases. Silica can be reduced internally in the boiler water by the addition of magnesium, but excess phosphates hinder this reaction. In general, there appeared to be a greater tendency toward scaling and deposition at 1500 psi than at 800 psi.

Ion Exchange Water Conditioning

In one of two papers on ion exchange water conditioning, W. D. Manring, of American Cyanamid and Chemical Corporation, dealt with "Demineralization of Water by Ion Exchange," and described the operation and performance of the Ionac Four-Bed System. A new development in ion exchange resin systems is the use of multiple beds which are regenerated in parallel with different solutions and then rinsed in series. At a cost of about six cents per thousand gallons for each hundred parts per million of removable salts, the advantages of the four-bed system are

1. High quality of water produced.
2. Low rinse water losses.
3. Good regeneration efficiency.
4. Chemical removal of CO_2.
5. Uniformly neutral pH of the effluent.
6. Flexibility of operation.

Use of the four-bed system reduces ion leakage and reduces the amount of sodium in the effluent to less than 8 ppm consistently throughout a run. Application of this system to small portable unit stills, gives practically complete demineralization of water for potable and other use. Such units are available with capacities of 5 to 50 gal per hr.

A second paper on ion exchange units was given by R. B. Thompson, of The Dorr Company, who discussed "Some Fundamental Factors Affecting the Design and Operation of Ion Exchange Units." After testing six-cation and three-anion, commercial exchangers, the author drew the following conclusions:

Acid-regenerated cation exchangers give 1 to 3 per cent leakage of cations through the bed, which is not readily detected by usual tests. Leakage of sodium is proportional to the strength of the exhausting solution, or in other words, with highly saline waters better acid regeneration is necessary to produce water of the same quality as from a low saline water. Factors affecting leakage are the amount of alkalinity present, the rate of flow through the bed and the quantity of regenerant used. The rate of flow in terms of cubic feet of exchanger is of more significance than the rate of flow per square foot of bed.

Anion exchangers give practically complete removal of mineral acids and their capacity depends on the strength of the raw water as well as on the acid being removed.

Of paramount importance to the performance of an ion exchange unit is the raw water analysis, as this determines the type and also the quantity of regenerant used.

Electrolytic Softening

"Electrolytic Water Softening for Industrial Purposes" was the title of a paper by R. E. Briggs of the Metropolitan Water District of Southern California. This process employs the principle of ion migration under the influence of an imposed emf. In a three-compartment cell, having porous partitions, an anode and cathode are installed in the outer compartments. Under the influence of a 2 to 6 kwhr electric input per 1000 gal of final product, dissolved salt ions migrate through the porous partitions to the anode and cathode, effecting partial demineralization of the water in the center compartment. The porous partitions allow removal of the treated water without setting up disturbing flow currents.

Part of the process is chemical in that sodium ions, migrating to the cathode, become metal sodium which unites with water to form hydroxide which in turn precipitates the hardness ions of calcium and magnesium. The sludges are filtered out and the effluent is treated to adjust pH values. Some silica reduction occurs, probably by absorption by precipitated sludges that are usually present.

The amount of softening and reduction in concentration obtained, is proportional to the ampere-hours applied per gallon of water. Four to ten volts is the operating range, operation at four volts being more efficient but having a greater initial cost of installation. Performance with an 800-ppm raw water, having 360-ppm hardness, showed reduction of hardness to less than 100 ppm and reduction of total concentration to about 450 ppm. Sulfate, chloride and silica show about 50 per cent reduction.

Efficiency of separation depends somewhat on pH conditions, and some selective separation can be obtained by stage treatment under controlled pH conditions, with intervening filtration.

(*Continued from page 38*)

ready to operate at peacetime levels if coal could be secured. The United States, which is the only source of supply for civilian coal, is shipping about 40 per cent of the amount consumed by Italy before the war.

Poland Can Export Coal

Poland previously produced about 38,000,000 tons a year; but the westward expansion of Polish borders has incorporated areas of Germany which had a pre-war output of 30,000,000 tons, and during the war the capacity of the whole of Silesia was increased. Destruction of the Polish transportation system, harbors and the limited rail service to Russia act as serious breaks to Polish coal production. The new Poland is producing at a rate of 30,000,000 tons a year, approximately 35 per cent of this coming from former German Silesia. She has agreed to provide Russia with almost a million tons a month, and has made trade agreements with Denmark, Sweden, Norway, Rumania and Hungary.

In Czechoslovakia annual peacetime production was approximately 25,000,000 tons, and coal was exported principally to Austria and Italy. Because of destruction of transportation and mines, and lack of food and clothing, production is approximately 30 per cent normal.

The Allied Nations are shipping to Greece about 20,000 tons of coal a month from South Africa and the United States, but destruction there is so great that it will take a rebuilding of the industries and railways before major quantities of coal are required.

The almost complete destruction of the Donbas Basin placed Western Russia in the position of having practically no fuel supply. During the war it was necessary to ship coal by rail from the Urals to keep war industries going. Upon liberation of the Donbas Basin, in which the mines had been destroyed by the Germans, the Russians salvaged all that was possible and placed full emphasis on maximum production. The result was that they expected to operate them in 1945 at about 50 per cent of peacetime level.

The European nations that managed to keep out of the war are also in dire straits. Sweden has entered into a trade agreement with Poland for coal but as yet has received negligible supplies. The United States is now exchanging a small quantity for an equivalent tonnage of wood pulp and Swedish industries are operating on a limited schedule.

Switzerland, like Sweden, during the war continued to import coal from Germany, but with this source of supply gone, she is attempting to buy coal in world markets.

Germany needs coal but is not going to get it. In the French, British, and United States zones, a minimum of $2^1/_2$ million tons a month is required to hold German economy at the disease and unrest level. She will not receive this much coal which includes fuel for the railways, for operation of the mines, for cooking for the troops and miners, and fuel for essential hospitals. It does not include fuel for cooking or heating for the German civilian population, nor does it include fuel to operate German industry except that which is contributing its entire output to the Armed Forces.

From the foregoing, it can be seen that practically all Europe requires very substantial tonnages of coal. As to sources of supply, the United States can will and supply approximately 2,000,000 tons per month.